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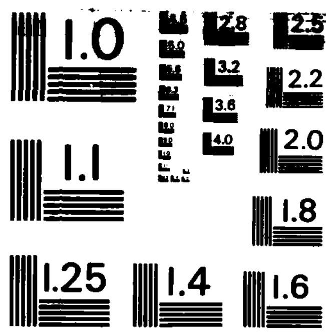

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AD-A141 040

Contractor Report 229

MITS II INVESTIGATIONS AND DESIGN ALTERNATIVES

Alexander Systems Company
D. L. Endicott, NOSC
Technical Coordinator

March 1984
Final Report
August 1983 — December 1983

Prepared for
Naval Ocean Systems Center
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NOSC

NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152

NAVAL OCEAN SYSTEMS CENTER SAN DIEGO, CA 92152

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J.M. PATTON, CAPT, USN
Commander

R.M. HILLYER
Technical Director

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A design study was conducted to investigate optional methods for the design and fabrication of a production version of the Microfiche Image Transmission System (MITS II). This second-generation facsimile is intended for high volume electronic transmission of microfiche personnel records from the Naval Military Personnel Command to major Navy facilities around the world. Major tasks in this design study include: 1) evaluation of alternative design approaches for improving the performance and reliability of the prototype MITS configuration (MITS I); 2) identification of commercially available components, systems, or related technologies which potentially satisfy MITS II functional requirements; and 3) preparation of a System Design

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20. Continued

Description which documents the results ~~of 1 and 2~~. Significant findings of this study include: 1) a new concept for a whole fiche scanner which requires a minimum of complexity in the film transport; 2) a mini-computer/microcomputer architecture for control and processing of image data and record request activity respectively; 3) incorporation of a high performance microfiche stack loader and bar code label identification; 4) a customized satellite telecommunications interface to optimize data transmission performance; 5) a commercially available laser computer output microfilm (COM) recorder which uses dry-processed silver halide film; 6) a recommendation to not implement multi-grey level scanning or recording for reasons of system throughput and hardware availability; and 7) selection of PASCAL as the most appropriate high order language for all custom system software.

FINAL TECHNICAL REPORT: MITS II INVESTIGATIONS AND DESIGN ALTERNATIVES

December 1983

SUBMITTED TO: NAVAL OCEAN SYSTEMS CENTER
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CONTRACT NO: N66001-83-C-0294

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ALEXANDER SYSTEMS COMPANY
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SAN DIEGO, CA 92121

FOREWORD

Merton,[1] a noted scientific historian, said that for the typical scientific paper there is a "rockbound difference between scientific work as it appears in print and the actual course of inquiry... The difference is a little like that between textbooks of scientific methods and the ways in which scientists actually think, feel, and go about their work. The books [or reports] on methods present ideal patterns, but tidy normative patterns... do not reproduce the typically untidy, opportunistic adaptations that scientists really make. The scientific paper presents an immaculate appearance which reproduces little or nothing of the intuitive leaps, false starts, mistakes, loose ends, and happy accidents that actually cluttered up the inquiry."

This final report of our MITS investigations is no exception to Merton's description.

TABLE OF CONTENTS

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LIST OF ILLUSTRATIONS

DICTIONARY OF ACRONYMS

A/D	-	Analog to Digital Converter
ADA	-	Structured, high level programming standard trademarked by the Department of Defense
ASC	-	Alexander Systems Company
BAUD	-	Digital Serial data rate measure
BPS	-	Bits per second
Byte	-	A group of digital data bits, usually 8
"C"™	-	Programming Language trademarked by Western Electric's Bell Laboratories
CCD	-	Charge Coupled Diode
CCIR	-	International Radio Consultive Committee
CCITT	-	The International Telegraph and Telephone Consultive Committee
CCPD	-	Charge Coupled Photo Diode
COM-Recorder	-	Computer output microform recorder
CRT	-	Cathode Ray Tube
DDCMP	-	Digital Data Communications Protocol
DMA	-	Direct Memory Access
DSX-1	-	Interconnect Specification for 1.544MBPS by American Telephone & Telegraph Company
ECC	-	Error Correcting Code
IBM-PC™	-	Microcomputer System. Manufactured and trademarked by IBM Corporation
IEEE	-	Institute of Electrical and Electronic Engineers
ITU	-	International Telecommunication Union
KTC	-	Establishes the noise level for charge coupled devices
MByte	-	One million bytes
MITS	-	Microfiche Image Transmission System
MPRS	-	Military Personnel Records System
MTBF	-	Mean Time Between Failure
MTF	-	Modulation Transfer Function
MTTR	-	Mean Time To Repair

Multibus™	-	Single board computer bus trademarked by Intel Corporation
MUX	-	Multiplexer
NMPC	-	Naval Military Personnel Command
NOSC	-	Naval Ocean Systems Center
NPRDC	-	Navy Personnel Research and Development Center
OEM	-	Original Equipment Manufacturer
PASCAL	-	Structured, high level programming standard
QA	-	Quality Assurance
Q-BUS™	-	Minicomputer bus trademarked by Digital Equipment Corporation
RAM	-	Random Access Memory
ROM	-	Read only memory
S/H	-	Sample and Hold circuit or device
SIC	-	System Integration Contractor
SSN	-	Social Security Number
STD Bus	-	A nonproprietary microcomputer bus jointly developed by Mostek and Pro Log Corporation
UNIX™	-	Operating System developed by Western Electric's Bell Laboratories
WFS	-	Whole Fiche Scanner

FINAL REPORT: MITS II INVESTIGATIONS AND DESIGN ALTERNATIVES

1.0 EXECUTIVE SUMMARY

1.1 Introduction

Alexander Systems was awarded a contract for "management and engineering effort related to an options analysis and design of a second generation version of the Microfiche Image Transmission System (MITS II). It [the contract work] does not entail fabrication, assembly, or installation of the system." Reference 2.

The contract requirements, Reference 3, called for:

"1) Evaluation of alternative design approaches for improving the performance and reliability of the prototype MITS configuration (MITS I)"

"2) Identification of commercially available components, systems, or related technologies which potentially satisfy MITS II functional requirements"

"3) Preparation of a System Design Description which documents the results of 1 and 2".

This final report presents the results of the effort called for by the contract. It includes the System Design Description.

1.2 Purpose

This document was prepared to present the findings of the MITS II investigations. In addition to the three general requirements listed above, the contractor was required to address

nine (9) specific technical improvement areas of the MITS I demonstration which the Navy had deemed necessary "to ensure successful application of the MITS technology to truly operational situations." See reference 4.

These specific technical assessment requirements (see reference 5) were:

1) Design of a high performance microfiche stack loader to facilitate high volume (1000 microfiche/day) transmission activity
2) Addition of a bar code label reader (Universal Product Code or equivalent) to the scanner to reduce the amount of keystroking required by the MITS operator
3) Methods for accomplishing multi-grey level scanning of fiche images (3 bits, 8 grey levels)
4) Methods for producing multi-grey level output microfiche (processing of grey level inputs, modulation of the writing beam, and film selection)
5) Improved operating system procedures (more user friendly, less operator keystroking)
6) Improved system software with assembly language code replaced by high order language code
7) Determination of satellite - compatible communications interfaces (data rates, buffering requirements)
8) Improved image detection and positioning (centering) for scanning
9) Improved system reliability and maintainability.

1.3 Summary of Findings

The result of our findings is a system level design which provides improvements responsive to all nine specific requirements, which employs up-to-date available commercial technology, and which, in our opinion, is affordable. We believe that these findings will be valuable to the Navy's MITS II program managers and to the eventual system contractor.

Some of the specific designs described herein are unique applications for MITS from related technologies. The Whole Fiche Scanner, described in detail in section 3.1, is the best example of this "technology transfer" approach. Without the WFS, or a design with equivalent performance, the system could not satisfy the volume requirement. The satellite link interface, described in section 3.4, is another example of our systems approach for overcoming a number of non-trivial technical problems.

Our approach for making MITS easy to operate ("more user friendly, less operator keystroking") was the result of work by engineering and behavioral science specialists. These people working together have produced, what we believe is, a subsystem design which is accurate, efficient and very well suited to the non-technical users of MITS. This design is described in section 3.9, Ergonomics, with other amplifying information throughout section 3.

1.4 Conclusions

The overall conclusive from our findings is that MITS can now move forward to final development and operational implementation. In other words, with this system level design, MITS can progress into detailed engineering design, fabrication and integration, installation, and training for the pilot system between Washington, DC and San Diego, CA.

2.0 RESULTS

The results of our engineering effort and technology survey is a system level design for MITS II. We believe that this design overcomes the problems encountered with the MITS I demonstration system, is affordable, and most importantly satisfies the Navy's overall MITS performance requirements.

The information in this report should be a useful technical guide to the Navy's program managers and to the eventual system integration contractor, SIC, for MITS II.

2.1 Functional Description

Figure 2-1 describes the human and hardware implementation of MITS II. The elements of the process are:

a. User request of his/her record at remote site (automated request chit).

b. Confirm requestor ID and process the request.

c. Forward request to NMPC.

d. Confirm authorization, ID check and request record from MPRS. Acknowledge user request.

e. Pull record, make duplicate, return master, perform QA, sort and load fiche scanner stack loader.

f. Scan record, digitize, and process. Report ID.

g. Transmit data to remote site.

h. Receive record data and process.

i. Produce high quality facsimile fiche records.

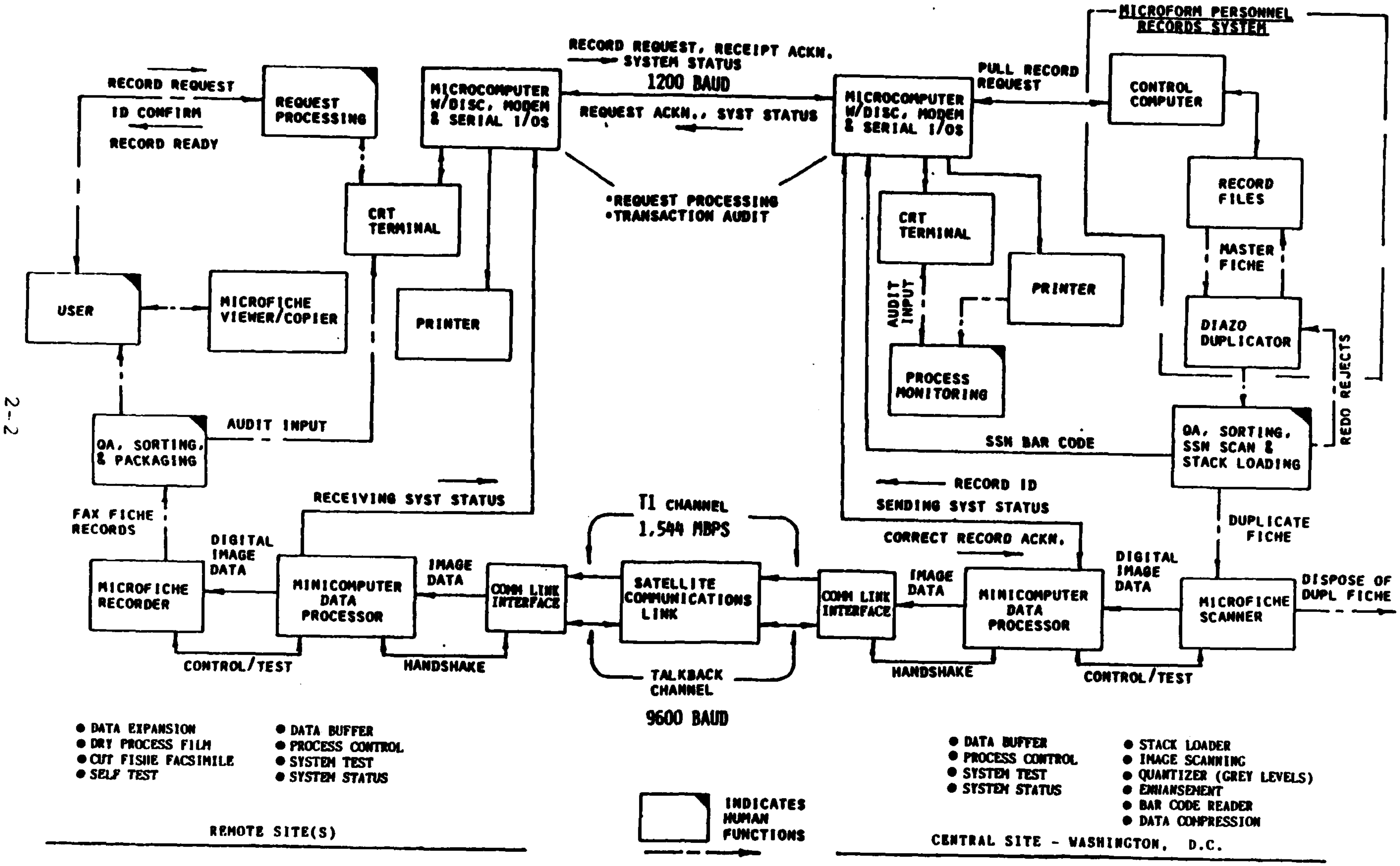


FIGURE 2-1 MITS II FUNCTIONAL BLOCK DIAGRAM

j. Acknowledge receipt of facsimile records and maintain audit reports.

k. Provide viewing facilities for the user.

l. Maintain service control and audit records.

2.2 Overall Performance Requirement

The MITS overall performance shall provide the following:

Input at Central Site	NMA Type 1, 24X, 98 image microfiche. Negative image polarity, Diazo duplicate of silver halide masters, 4.13" x 5.83" x .007".
Remote Site Output	Multigrey level, dry process, cut film, microfiche facsimile.
Scanning Resolution	200 pixels/inch of full-size original image. (4800 pixels/inch on microfiche).
Volume	300 Records per day, minimum. (1000 fiche/20 hour day)
Turn around	24 hours, max. Request-to-output. Priority request goal is 15 minutes.
Operating Hours	0400 to 0000 Remote Site Local Time.
Maintainance Hours	0000 to 0400 Remote Site Local Time.

Central Site Location	NMPC, Navy Annex, Washington DC.
Remote Site Location(s)	Naval Activity, San Diego, CA. (Others later)
Management/ Operation Personnel	
at NMPC	Civilian clerical
at Remotes	Navy military

2.3 Hardware and Software Summary Description

Hardware

It is the Navy's intent that MITS be built using reliable state-of-the-art, commercially available hardware wherever possible. It is recognized that some hardware elements will require modification or adaptation in order to satisfy performance requirements. Other parts of the system will require new hardware designs. This work would be performed by the equipment supplier and/or the system integrator.

Major equipment elements in the initial system are:

- Two microcomputer systems - one at the remote site and the other at the central site. Each would include dual floppy disk, CRT terminal, printer, 1200 baud modem, and additional serial I/O. These linked microcomputers are the transaction processors.

- Microfiche Scanner with stack loader and film transport; image scanning optics, mechanisms, electro optics, and electronics; pixel signal quantizer; realtime image enhancement electronics; data compression; and control/data interface to the central site minicomputer.
- Two minicomputer systems from the same family - one at the central site and the other at the remote site. The central site minicomputer performs image data buffering, scanning and transmission synchronization, system testing and status reporting. The remote site minicomputer performs data receiving and recorder synchronization, data buffering, system testing and status reporting.
- Two T1 Communication Channel Interface Units for interfacing between the minicomputers and the satellite communication link.
- Microfiche Recorder which accepts the compressed digital image data from the minicomputer and produces legible dry process, cut film microfiche facsimiles.

The satellite link will be leased service from a commercial provider.

Software

Our system level design calls for the use of commercially available minicomputers and microcomputers. Selection of that

equipment establishes operating system software for both.

For the minicomputers, a structured high level programming language (Pascal) has been selected for the development of application programs for main process control. The recommended version is supported by the realtime operating system. This choice overcomes the software problems encountered with the MITS I demonstration system. It also provides much better software documentation and eases the burden of future software maintainance.

For the microcomputers, a number of single user operating systems are available. Some of the OSs support high level structured programming languages such as UNIX, Pascal and C. Many of the available third party application programs are written in these structured languages. The SIC for MITS II, should find some of this available software to be suitable for the transaction processors. The type of business application programs in this catagory are order entry, inventory control, flow process monitoring and perhaps general ledger for the audit trail.

2.4 Results of Commercial Survey

As part of our analysis effort, we have made inquiries to over 50 companies in the electronic imaging and communication industries. See Appendix B. The majority expressed an interest in MITS - either as candidate SIC or as subcontractor to the SIC for parts of the system.

After reviewing the responses to our initial inquiry, we made follow-up calls or had face to face meetings with those companies

who helped to provide answers for the major problems.

In section 3 of this report we describe the details of our analysis effort and our system level solution to the Navy's need.

In some cases, we reference our contacts during the technology survey and provide specific technical information such as: "Company X does it this way". These statements should in no way be construed to mean that their products or services provide the only future solutions for MITS II. Some of these statements do mean, however, that in our professional opinion, their products or service offer the best solutions at the present time.

In summary, the result of the commercial survey made it possible for us to produce the system design reported in this document.

2.5 Summary of Recommendations

The following sections present a summary of our design with specific hardware and software recommendations. References to those parts of section 3 where the technical detail can be found are also provided.

In developing this sytem design, we tried to make use of suitable commercial equipment wherever possible. The overall system was first divided into two subsystems; the Transaction Process Subsystem and the main Microfiche Scanning, Data Transmission and Facsimile Production Process Subsystem.

2.5.1 Transaction Process Subsystem

The transaction process is a "business type" process requiring capabilities for handling operations such as order entry (Record Requests), accounting or auditing (transaction audit), forms preparation (Request Chit), etc. In our investigations we found compelling reasons for recommending a separate subsystem for transaction processing. These reasons include: a) More user friendly - Equipment and software is closely matched to the experience and skill levels of the operators, b) Higher productivity - Microcomputer based system is highly automated. Almost all operator keystroking is eliminated, c) Increased reliability - Eliminating the transaction process burden from the main process controllers (minicomputers) allows them to perform extensive system monitoring, system test and fault localization, d) Lower overall cost - In each subsystem, the process controllers are better matched to the particular process. The main process is an "industrial type" flow process better served with a small minicomputer for process control. Because of the difference between the two processes, it is cheaper to use separate process controllers that are precisely matched to the process needs.

Our recommendation for the transaction process subsystem is the use of linked IBM-PC microcomputers. The communication links between the remote sites and the central site is via 1200 baud modems and telephone lines. The centrol site microcomputer interfaces to MPRS computer to automate the "Pull Record Request." Our estimate for hardware and software cost is $14,000 (Central

and one remote site). The details of this subsystem can be found in section 3.9 below.

2.5.2 Main Process Subsystem

The main process can be compared to an "industrial type" flow process such as a steel mill, chemical refinery, concrete batch plant, etc. In a continuous industrial flow process, raw materials or feed stock are operated upon to produce an output product. For MITS II, the feed stock is the diazo duplicate of the microfiche record at the central site and the output product is the facsimile fiche record produced at the remote sites. The following sections summarize our recommendations for the main process hardware and software.

Microfiche Scanner

In our investigations we could find no commercial equipment which would satisfy the requirements of the scanner. We could not even find a scanner which could serve as the basis for adaptation or modification. Therefore, we produced a top level design for what we call the Whole Fiche Scanner (WFS) and we recommend the WFS for MITS II.

The pieces and parts of the WFS design have all been used previously in other applications. The WFS consists of:

a) Stack loader and fiche transport

b) Fiber optic bundle

c) A set of electro optic arrays

d) Video processing and image enhancement electronics

e) Image data compression electronics

The details of the WFS can be found in section 3.1 below.

Process Control Minicomputers

We recommend the use of Digital Equipment Corporation (DEC) LSI-11, Q Bus, minicomputers at all sites. Machine configuration and function is described in sections 3.3 and 3.5. All hardware is off the shelf. There are over 300,000 Q-Bus systems in use today; many are for process control applications similar to the MITS II requirements. The hardware at all sites is identical. The estimated cost of the minicomputer system is $25,000 per site.

Satellite Link Interfaces

As in the case of the scanner, no commercial equipment could be found for the image data communication interface requirements for MITS II. Therefore, we provide a top level design for the interface units as described in section 3.4 below; we recommend this design.

The estimated cost of the interface units range between $12,000 and $50,000 per unit plus engineering development cost between $20,000 and $100,000.

Microfiche Recorder

As the result of our investigations, we recommend the adaptation of a commercially available laser beam, dry process film COM Recorder for MITS II. Specifically we recommend the use

of the ARIS II COM Recorder manufactured by Datagraphix, Inc.

Section 3.8 provides the details of our investigations and findings. The basic ARIS II COM recorder costs approximately $102,000. We can provide no estimate for the cost to adapt the basic recorder to satisfy the MITS II requirements.

Main Process Software

As the result of our investigations, we recommend the use of MicroPower PASCAL for the minicomputer applications software. The details for this choice is described in section 3.6. The recommended PASCAL is compatible with the operating system (RT-11) and has found wide use in industry. The cost, with highest level license, is approximately $2,000.

3.0 SUBSYSTEM ANALYSIS

As described in Section 2.1, Functional Description, above, the MITS II is broken down into subsystem elements for further design analysis. First the overall process is divided into two major subsystems: 1) the microcomputer based transaction process subsystem, and 2) the main image scanning, data handling and transmission, and facsimile production process subsystem.

Because the second process involved the bulk of the engineering investigations (and the majority of the problems), its elements are discussed first. The transaction process subsystem is then discussed in Section 3.9, Ergonomics.

The logical starting point for the main process investigations is to establish overall system performance parameters and then to further break down these overall parameters to the affected subsystem elements.

It is obvious that the throughput performance of the main process is bounded by the satellite link's image data rate and other "given" constraints.

For example, we can establish the parameters for hardware element performance by the following:

Given: 1) Each reduced image is 10.0mm x 12.5mm

2) Resolution required is 4800 lines per inch

3) T1 data rate, max, is 1.544 MBPS

4) Throughput Volume is 50,000 images per day

Assumptions: 1) Image Data Compression Ratio is 5:1

2) Comm Link Protocol Efficiency Goal is 95%

3) One bit per pixel quantizer output of scanner (or input to compressor)

Find: 1) Time to transmit one image

2) Process Controller Throughput

3) Scanner Throughput (speed)

4) Recorder Throughput (speed)

5) Data Buffering Requirement

Calculations:

Pixels/Image

The quantity of uncompressed image data, Q, for 1 bit/pixel:

$$Q = \frac{10\text{mm}}{25.4\text{mm/inch}} \times \frac{12.5\text{mm}}{25.4\text{mm/inch}} \times (4800 \text{ pixels/inch})^2$$

$$Q = 4.464 \times 10^6 \text{ pixels/image} \qquad (3\text{-}1)$$

Compressed Image Data

With 5:1 compression and one bit per pixel quantizer, the compressed data quantity is:

$$Qc = 4.464 \times 10^6 \div 5$$

$$Qc = 8.928 \times 10^5 \text{ bits/image} \qquad (3\text{-}2)$$

Comm Link Image Throughput

With 95% protocol efficiency the data rate of the satellite link is:

$$R_{max} = 1.544 \text{ MBPS} \times 0.95$$

$$R_{max} = 1.4668 \text{ MBPS} \qquad (3\text{-}3)$$

and the time required to transmit one image worth of data is:

$$T = (8.928 \times 10^5 \text{ bit/image}) \div (1.4668 \times 10^6 \text{ bit/sec})$$

$$T = 0.6087 \text{ sec/image} \qquad (3\text{-}4)$$

Thus, we see that each image requires approximately 0.61 seconds to be transmitted via the link. Next, consider system throughput or operating time for a "perfect" process.

System Throughput

For a 20 hour operating day, the number of total images possible is:

$$T_I = 72{,}000 \text{ sec} \div 0.6087 \text{ sec/image}$$

$$T_I = 118.3 \times 10^3 \text{ images} \qquad (3\text{-}5)$$

The calculations above provide bounds upon the required performance parameters of the hardware elements of the main MITS process. They also provide clues upon which to base other trade-offs. For example, we can see that with the assumed compression

ratio and protocol efficiency it would be impossible to handle the required volume (50,000 images per day) if each pixel were quantized to 3 bits instead of only one bit (3 bits = 8 grey levels).

This fact tells us that whatever quantizing value is used in the scanner's enhancement electronics, the output (input to compressor) stage must be a clipper or scaler to produce one bit per pixel.

The results above also show that the process must be continuous. In other words, little time is available for "overhead" such as positioning on new images, the fiche transport in the scanner, repeating bad blocks of image data transmission, recorder film transport, etc.

These calculations show that MITS must be able to "process" each fiche (up to 98 images) in no more than approximately 60 seconds. This value places an upper bound (or goal at which to aim) upon the system designers in their investigations of the various subsystem elements.

The results above led to the conclusion that the image data buffer (hard disk storage) should have the capacity to store at least one fiche worth of compressed image data.

Data Buffer Storage

Equation 3-2 shows that each document image contains 8.928×10^5 bits of compressed data. The eye readable header area of the fiche contains approximately 1.2×10^5 pixels at the lower

resolution of 200 lines per inch. If the header information is scanned, quantized to 1 bit, and compressed by 5:1, the header would contain approximately 2.4×10^4 bits of compressed data. Each fiche has a maximum of 98 document images.
Therefore the total maximum of compressed image data on one fiche is:

$$
\begin{aligned}
Q_{TF} &= 0.24 \times 10^5 \text{ bits} + 98\ (8.928 \times 10^5) \text{ bits} \\
&= 875.2 \times 10^5 \text{ bits} \\
&= 87.52 \times 10^6 \text{ bits} \qquad (3\text{-}6)
\end{aligned}
$$

Note that the header data is a small part of the total (Approx. 0.003%).
If we assume an efficiency of 0.875 for packing the bits into 8 bit bytes, the total number of bytes for storage becomes:

$$
\begin{aligned}
Q_{BYTES} &= 87.52 \times 10^6 \text{ bits} \div (.875 \times 8 \text{ bits/byte}) \\
&= 12.50 \times 10^6 \text{ bytes} \qquad (3\text{-}7)
\end{aligned}
$$

Therefore, to store one whole fiche worth of compressed image data, a disk with at least the capacity of 12.5 MBytes (Formatted) is required.

Summary

1) The time required to transmit one document image is 0.6087 seconds (compressed data).

2) The process controller should aim at a throughput of 118.3 x 10^3 images per 20 hour day.

3) The satellite link interfaces should aim at a data throughput of 1.467 MBPS. To meet this goal a high efficiency protocol is needed.

4) The scanner should scan, enhance and compress the data for one fiche in no more than 59.7 seconds.

5) The recorder should be capable of accepting the compressed data and producing a cut facsimile fiche in no more than 59.7 seconds.

6) The minimum compressed data buffering requirement for one fiche is 12.5 MBytes.

3.1 Microfiche Scanner

The scanner is the system element which required the greatest part of the analysis effort. There are no easily modified commercial products available to perform the MITS II scanner functions. Our definition of the scanner includes:

a) Stack Loader and Film Transport

b) Scanning Optics

c) Electro Optic Device(s)

d) Video Processing Electronics

e) Image Enhancement

f) Data Compression and Encryption

Our Statement of Work requires that we specifically address four (4) task areas which directly relate to the scanner. These are:

a) Design of high performance microfiche stack loader...

b) Addition of a bar code label reader...

c) Methods for accomplishing multi-grey level scanning...

d) Improved image detection and positioning (centering) for scanning.

During our investigations we have discovered direct solutions for the first two problem areas - Stack Loader and Bar Code Reader. For the latter two, indirect solutions have been found for the problems which are the result of given conditions on the original microfiche. In many cases the original image on the fiche has very low contrast. The images are also skewed and shifted from their "normal" position in making up the master

fiche. Hence the requirement to address multi-grey level scanning and image detection and centering.

But as noted earlier, the direct solution of multi-grey level scanning conflicts with the system's throughput requirement because of the capacity of the satellite communications link. A more comprehensive approach was needed. Our approach was to investigate, discover and devise a design with image enhancement which overcomes the basic problem of low original contrast.

To overcome the problem of image detection and centering, our investigations led to a state-of-the-art technique for scanning the whole fiche. The Whole Fiche Scanner, WFS, also provides other benefits. These are higher scanner throughput because of parallel image processing and higher reliability because of the simple, one dimensional, mechanical film transport. Note that the scanner head is fixed. The WFS will be described in the sections below.

At the beginning of this section, we stated that there were no commercial microfiche scanners available which could be modified (with either ease or great difficulty) to satisfy the MITS II needs. However, there are commercially available, proven, parts and pieces for the scanner we discuss below. For image enhancement alone, one potential MITS II contractor was able to demonstrate his existing hardware with dramatic results. In other scanner areas, we discuss only hardware which has been proven in real world applications.

Although the data compression is a functional part of the scanner and should be contained in the same physical cabinet, we

have chosen to include our discussion of data compression in Section 3.2 of this report. This is done for two reasons. First, we were not specifically tasked to perform a rigorous investigation because another contractor is doing this work for the Navy. Secondly, the system level interfaces and functional requirements are easily defined. Our discussions with the experts in data compression have been very useful in the overall system design.

3.1.1 Stack Loader and Fiche Transport

Figure 3-1 shows a design of a stack loader and fiche transport for the MITS II scanner. This preliminary design is based upon a similar X-Ray film scanner mechanism built by Mekel Engineering, Inc. of Walnut, California. See appendix B. The operation of the mechanism is as follows (Ref 6):

a) The loading tray is pulled out and a stack of up to 100 fiche is stacked in the recess in the tray. The header of the fiche are placed to the rear of the tray.

b) The tray is pushed into its operating position and a sensor detects that the operation can begin.

c) The vacuum platen is lowered to the top of the stack.

d) The vacuum platen lifts the top fiche up to the level of the clamp. The clamp is actuated to grasp the very top edge of the fiche.

e) The clamp (transport) with the fiche are driven horizontally by the lead screw such that the bar code and the fiche itself are scanned.

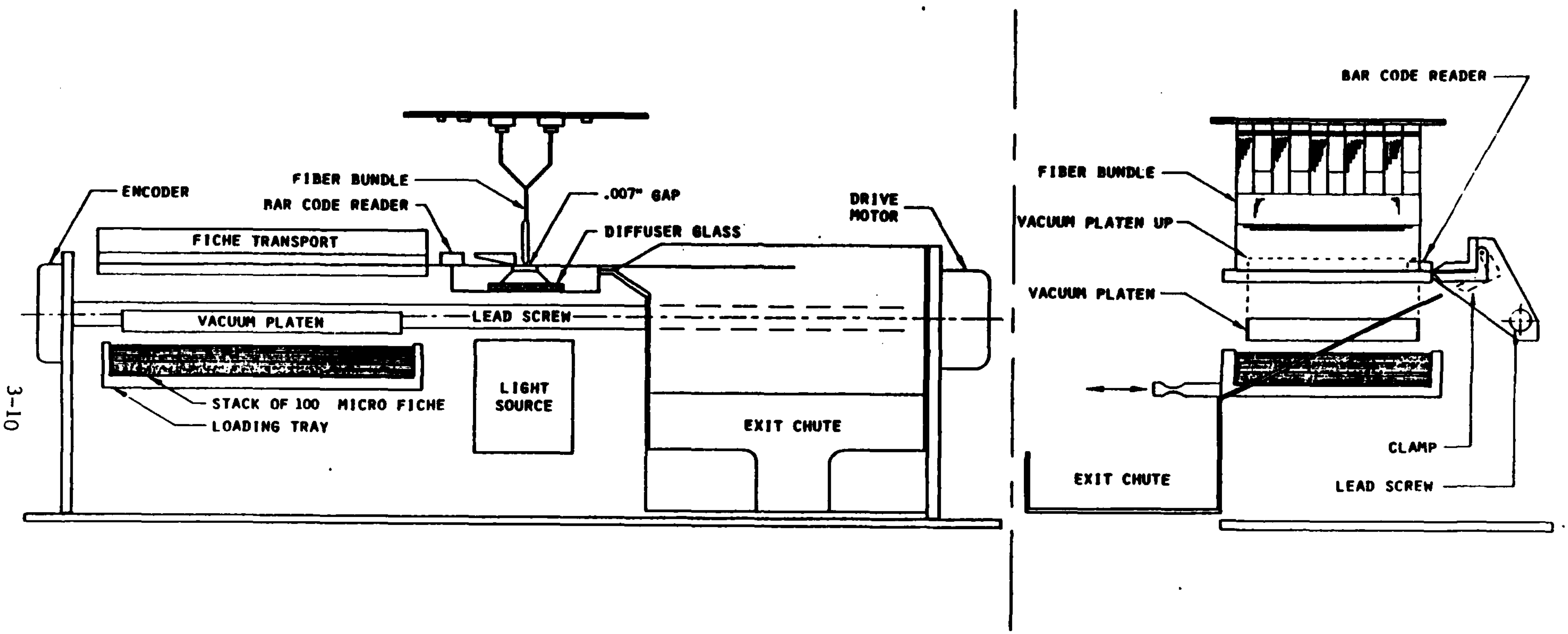


FIGURE 3-1 STACK LOADER AND FICHE TRANSPORT

f) When the transport reaches the end of its travel, the clamp is released and the fiche falls into the exit chute. At the bottom of the chute is the exit tray.

g) After dropping the old fiche, the transport makes a rapid return to the pick-up position where it is ready for the next fiche.

The assembly is designed for minimum maintenance. All bearings are lifetime lubricated and its enclosure would be sealed to minimize dust and light leakage. Cooling fans will need to be equipped with good quality filters.

Sensors will be needed to detect both "low" and "empty" input stack. This information would be given to the operators via the minicomputer controller and microcomputer.

Other sensors will be needed to provide status information such as film jams, motor overheating, etc. These status flags would also be fed to the main process controller.

3.1.2 Fiber Optic Bundle

Early in our analysis we found that the system could not satisfy the volume or throughput requirement (50,000 document image/day) if only one image is scanned at a time. The pixel time of a single Electro Optic Sensor is simply too high. An obvious answer is to have multiple sensors and parallel electronics up through the video signal processors. But multiple sensors causes a complex optics requirement.

Let us assume that we pick ten (10) as the number of EO linear arrays. We would need ten sets of optics (lens) - one for

each array. This scheme is complex and expensive.

A simpler proven scheme is the use of fiber optics. In other applications, optical fibers have been used to couple the light from individual pixels onto the photosites of rectangular Electro Optic arrays. Thus, we know that it is possible to produce a very long linear fiber optic array. The trick then is to breakout sections of this long fiber array into ribbons which "connect" to the individual EO arrays. The position of each EO array photosite is very precise. The position of the individual fibers in the ribbon end is also very precise. But there must be some method for calibrating or aligning the fiber array to the EO photosite array when the connection is made. The connection also needs to be a "make" or "break" connection instead of a potted connection. This point is a repair consideration. We would not want to throw away the whole expensive assembly if or when one of the EO arrays fail.

Figure 3-2 illustrates the concept of the fiber bundle. The bundle contains approximately 20,000 individual contiguous fibers. Each fiber is approximately 5 micrometers (micron) in size. The ribbon ends connect to EO arrays which are part of the video processor modules. The modules mount on a PC board.

Figure 3-3 illustrates conceptually how this scanning head is mounted in the scanner mechanism. The illustration shows how the fiche is moved past the head of the long fiber optic bundle. Note that the fiche transport simply carries the film past the head in one dimension without the need for back tracking or "image centering".

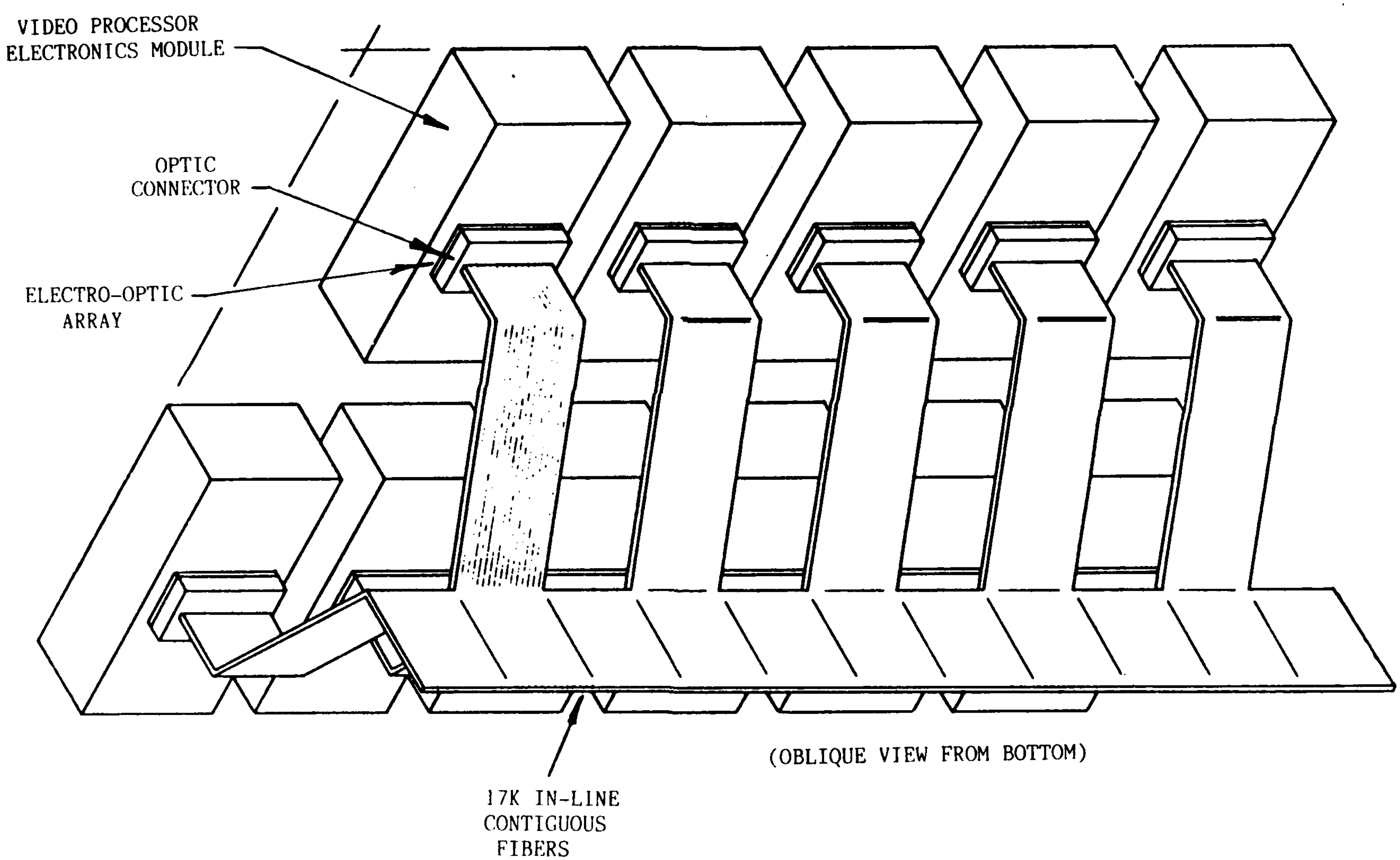


FIGURE 3-2 FIBER OPTIC BUNDLE

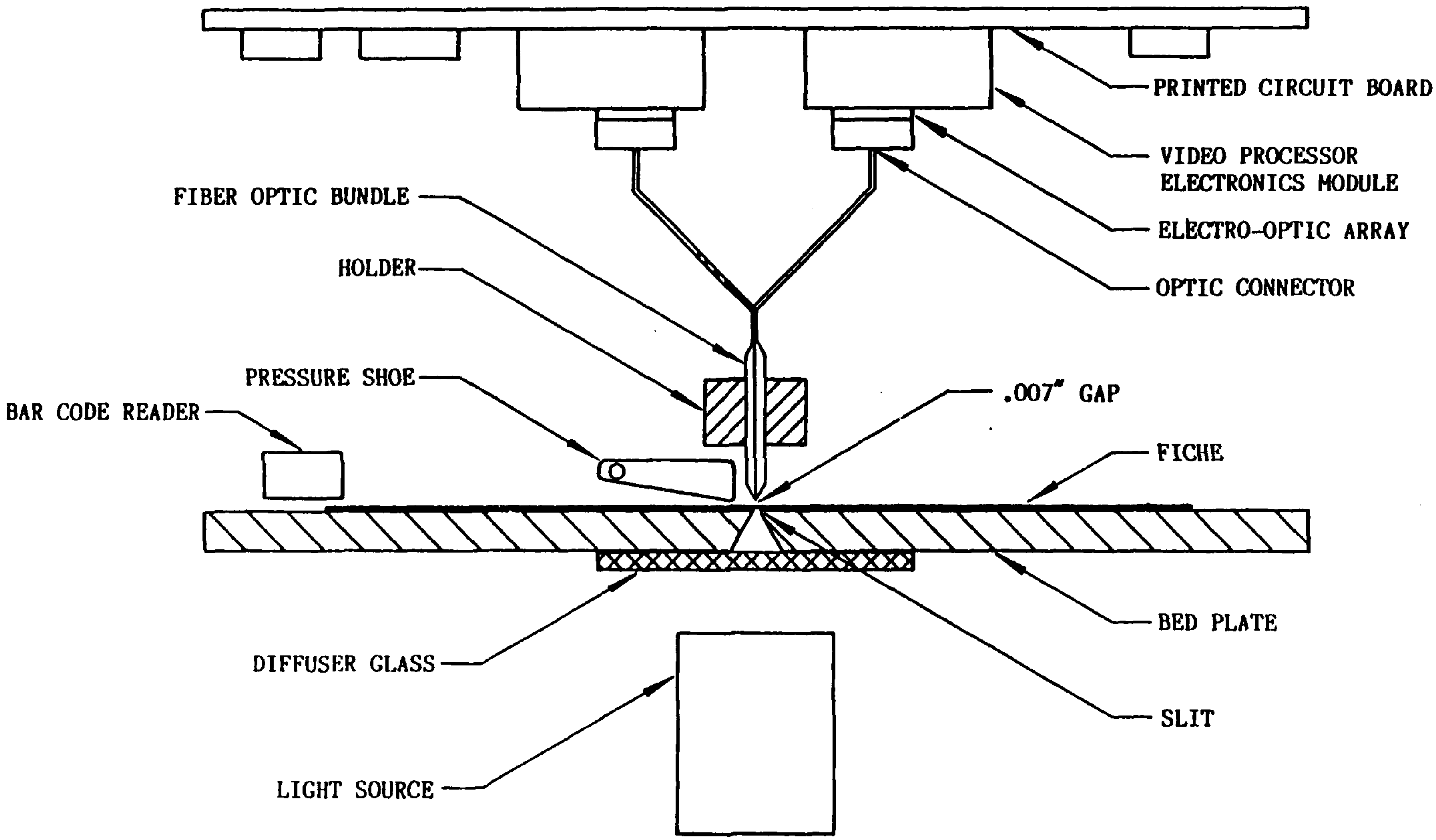


FIGURE 3-3   SCANNING HEAD TRANSPORT

The fiber optic bundle makes it possible to scan the whole fiche in a single pass. The fiber optics described above will require some development effort for MITS II. The overall concept has been proven. A two dimensional fiber bundle with approximately 3 million fibers has been built. We recommend that the fiber optic bundle, with connections to electro optic array photosites, be included in any scanner development phase work.

3.1.3 Electro Optic Arrays

Three types of EO arrays have been considered in this analysis. These are: a) Charge Coupled Diodes (CCD), b) Charge Coupled Photo Diodes (CCPD), and c) Diode Arrays.

In the past, the CCDs showed a marked advantage - that of small pixel size (down to 6 micron). However, recent technology advances in IC design has given thrust to smaller pixel size (down to 3 micron) as well as other advantages. See references 7 and 8. Using high level integration, these monolithic devices combine a more sensitive and less noisy diode array with a charge coupled register for multiplexing, collecting a charge, and shifting the charge off of the chip.

The pioneer in this effort has been Reticon who also did much of the early work with CCPDs. More common linear arrays are the CCD and Diode Arrays. The leaders in their development were Fairchild and Reticon. A later arrival was Texas Instruments. The pure CCD has always been plagued by KTC (thermal) noise (Refs 9,10,11 & 14), poor dynamic range, lack of speed and low yield. Likewise, the Diode Array has had its problems. These include,

large pixel size and some early noise problems; primarily dark current noise.

By combining the CCD and CCPD technologies, and achieving some IC process breakthroughs, an EO Array with significantly greater utility (usefullness) has been developed. Still hampered by short array length, the line transfer CCPD (Reticon CCPD 1024) has useful features. It has an integration command that places a precharge bias on the array which permits the reading out of signal and integration to be entirely separate. This allows fast readout of data (signal) when transferred from the diode array to the CCD register. This might be an application for MITS because it would allow the device sufficient integration time with burst mode read-out at the maximum clocking rate. See Figure 3-4. The technology now requires less metalization and the associated process steps of the CCD photosites. This breakthrough has increased yield by orders of magnitude and reduced per unit cost. Although these new devices still suffer from complicated clocking requirements, they are far better than the older CCD and CCPD arrays.

Some advances have been made in imaging CCD technology. These include the faster imaging CCD (Fairchild CCD 133 and 143 in Table 3-1) and the TI "Virtual Phase" devices (TI 101 through 104).

Fairchild's higher speed (up to 20 MHz) is an improvement of older devices such as the CCD 122 but the increased speed is achieved at the cost of reduced dynamic range. In fact dynamic range is so reduced that even at 10 MHz virturally no

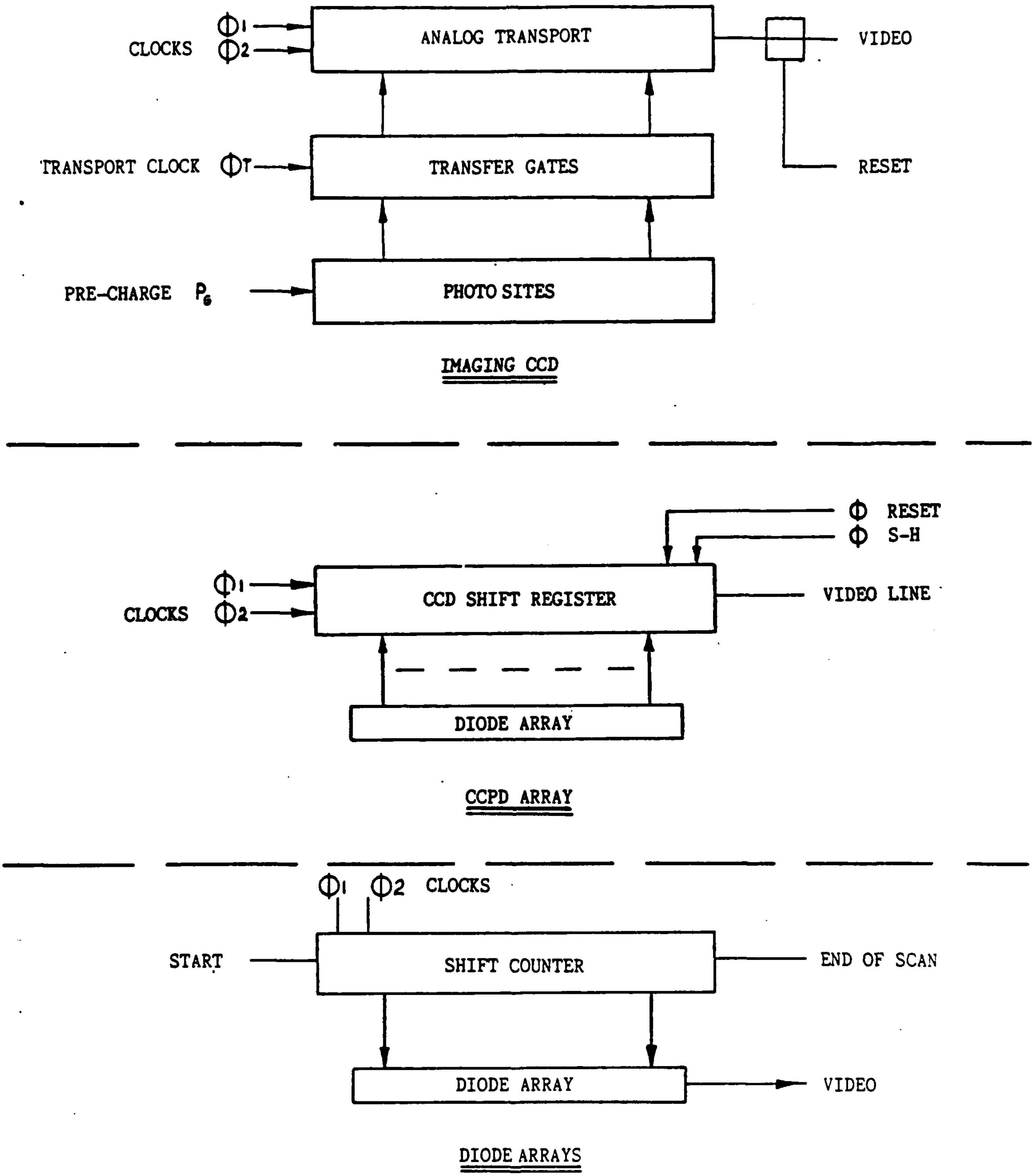


FIGURE 3-4 ELECTRO-OPTIC ARRAYS

specification is given. The major noise contribution is the capacitive coupled clock artifacts introduced by higher element capacity.

TI's virtual phase devices, Reference 13, might be candidates for MITS because of the relative ease with which the devices can be clocked. But their line of EO sensors suffer from lower pixel clocking speed, lower yield due to increase integration of the clocking structure (permitting virtual phase clocking), and the "on again-off again" marketing attitude of TI. For example, TI has almost abandoned the virtual phase design for their two dimensional CCD imagers. The reason is <u>very</u> low yield. This may explain their lack of marketing zeal and causes one to ask, "How long will the virtual phase devices be available?"

Based upon this analysis, we believe that either Fairchild or Reticon would be good sources for the EO sensors. Neither company supplies directly compatible second source devices for the other. Although not pin for pin compatible, they both do offer clock compatibility and could be interchanged with relative ease.

3.1.4 Clock Drive, Video Processing and Multiplexing

Clock Drive Electronics

Clock Drive signals are applied to the Electro-Optical imaging device (CCD, CCPD, Diode Array) in the form of a multi phase, bipolar signal. In addition to the clock signal, others which must be provided in sync with the clock signals are the reset gate, array start and pixel clamp.

TABLE 3-1

CANDIDATE IMAGE SENSORS

DEVICE NO.	TYPE	MFG.	PIXEL SIZE (μM)	NO. OF ELEMENTS	NAX SCAN RATE(MHz)	DYNAMIC RANGE	FIBER OPTICS	COMPLEXITY/ INTERFACE
TC 101	CCD	TI	12.7	1728X1	-	> 1000	?	Very Low (Virtual Phase)
TC 103	CCD	TI	12.7	2048X1	-	> 1000	Yes	Very Low (Virtual Phase)
TC 104	CCD	TI	10.7	3456X1	-	> 1000	No	Very Low (Virtual Phase)
1024SF	DIODE	RETICON	25.0	1024X1	5	> 2000	Yes	Medium (40)
RC1728H	DIODE	RETICON	15.0	1728X1	3	∿ 1500	Yes	High (No On-chip RESET)
RL4096	DIODE	RETICON	15.0	4096X1	10	1000+	No	60 Clocks
CCPD 1024	CCPD	RETICON	18.0	1024X1	8	2000	Yes	Fast line Readout, 8 μS
CCD 121	CCD	FAIRCHILD	13.0	1728X1	1	500@1MHz	Yes	High (40)
CCD 122	CCD	FAIRCHILD	13.0	1728X1	1	≈ 2000	Yes	Medium (20)
CCD 142	CCD	FAIRCHILD	13.0	2048X1	1	≈ 2000 *	Yes	Medium (20)
CCD 133	CCD	FAIRCHILD	13.0	1024X1	20	≈ 2000	Yes	Medium (20)
CCD 143	CCD	FAIRCHILD	13.0	2048X1	20	≈ 2000	Yes	Medium (20)

* NOTE: Frequency at Specified Dynamic Range Not Given. Understand poor at Fmax.

To reduce noise and capacity these clocks must be located very close to the EO array itself.

Clocking speeds are determined by the scan rate and integration time. With the candidate EO arrays listed in Table 3-1, this speed could reflect pixel rates up to 10 MHz or 100 ns.

For a more compact design (depending on which document scanning technique is chosen) these clocking signals could be generated by a common clock driver. However, there are trade-offs such as noise and capacitance generated by clocking distribution that may impact this approach. Still it must be considered as a factor in reducing the overall circuit complexity if the Whole Fiche Scanner is employed.

Video Processor

The Video Processor provides A.C. gain, D.C. restoration, and a means of holding (sample & hold) the signal for digitization.

All array electronics (preamp, clock drivers, video processor) which are peculiar to the EO devices could be packaged into one small assembly. Although this sounds complicated, the amount of electronics within this section is very small and consumes little space.

Multiplexer

The Multiplexer accepts samples and holds video levels and feeds them to the digitizer. With the fiber optic bundle, one must look at all the EO arrays as one contiguous optical array. However, each EO array is electrically in parallel except for the

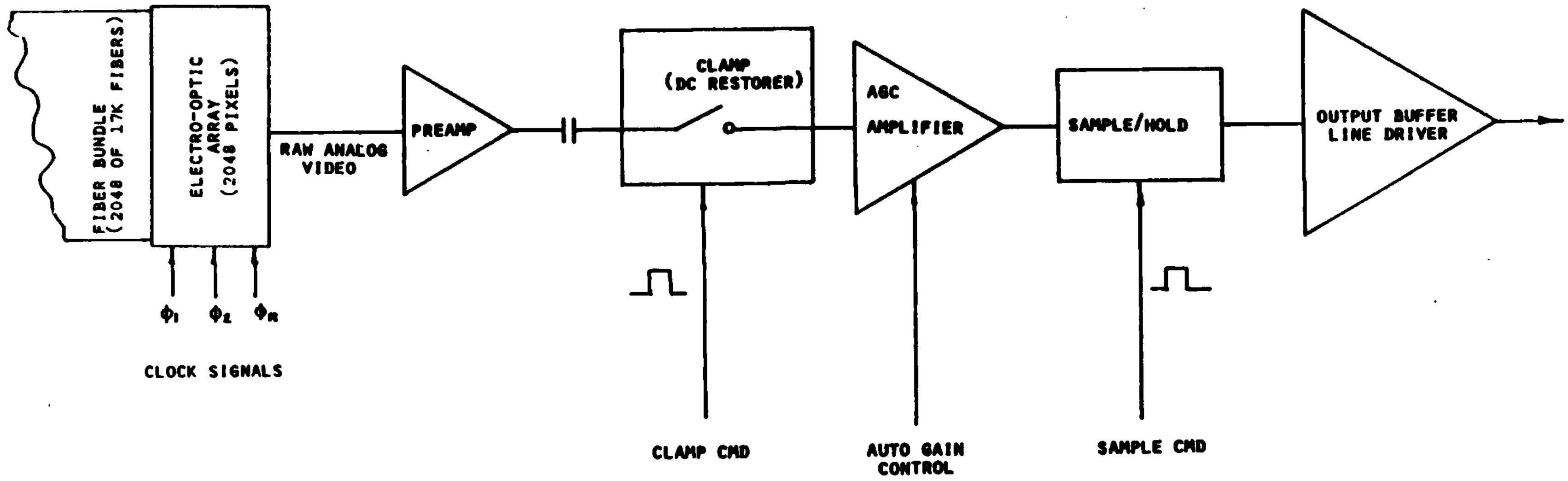


FIGURE 3-5 VIDEO PROCESSOR

video output which is sampled at a subpixel rate of 50 ns. Thus the multiplexer will switch at the end of each pixel (1024, 2048, 4096 pixels). See Figure 3-6. Its switching rate will be fast in comparison to the pixel rate.

The MUX Rate can be expressed as:

$$R = \frac{\text{Pixel Rate}}{\text{Number of Arrays}} \qquad (3\text{-}8)$$

Output of the multiplexer will be fed directly to the digitizer which will be operating at a sample rate of approximately 50 ns.

Quantization will be to a 6 bit level only, because this is economically achieved in a single integrated circuit. Greater dynamic range is not required.

The digitized output is then fed to the buffer memory. A two line buffer memory is used to reduce the pixel rate. This buffer is used to utilize the total integration time (line scan time and mechanical stabilization time) which will be greater than 1 ms. See further discussion under "Timing Considerations" in section 3.1.6 below.

3.1.5 Image Enhancement (Convolver)

The following discussion is intended to serve as technical guidance for the MITS II development engineers. The general reader may wish to skip this section and go on to section 3.1.6 for the highlights of the WFS.

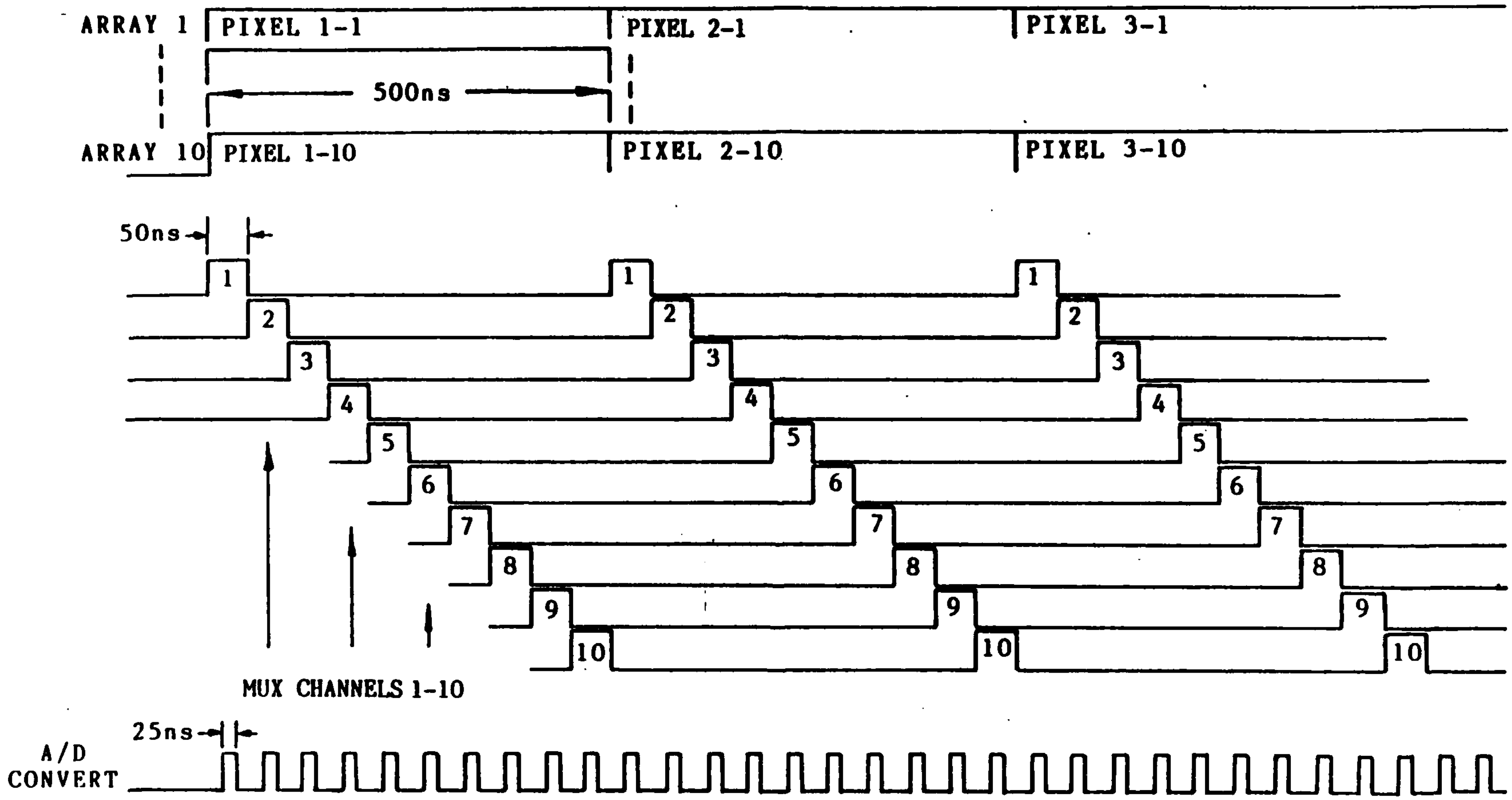


FIGURE 3-6 TIMING DIAGRAM, MULTIPLEXER

Theory of Operation (Reference 15 and 16)

Realtime, two dimensional, high and low pass spatial filtering is accomplished by a convolution that digitally convolves the realtime image with either a square (N X N) or rectangular (N X 1) filter function where N is an odd number from 3 to 7.

Simply stated, the filter function can be considered to be composed of two elements: 1) a "kernel" which is the sum of the pixel values in either the square or rectangle, and 2) a "centroid" which is the value of the centermost pixel in the kernel multiplied by a constant or a functional variable. The variable is used in those cases where the texture of the image is widely varying. In those cases, the variable is a function the type of image being processed.

Convolution is implemented in real time by replacing every pixel in the unfiltered image with either the sum of its surrounding kernel and centroid (low pass), or with the difference between the centroid and the surrounding kernel (high pass). See Figure 3-7.

Convolution in the spatial domain is equivalent to multiplying in the frequency domain, the spatial frequency spectrum of the original image by the frequency response of the filter function. The frequency response of the filter function can be thought of as a summation of the frequency responses of the kernel and the centroid taken individually.

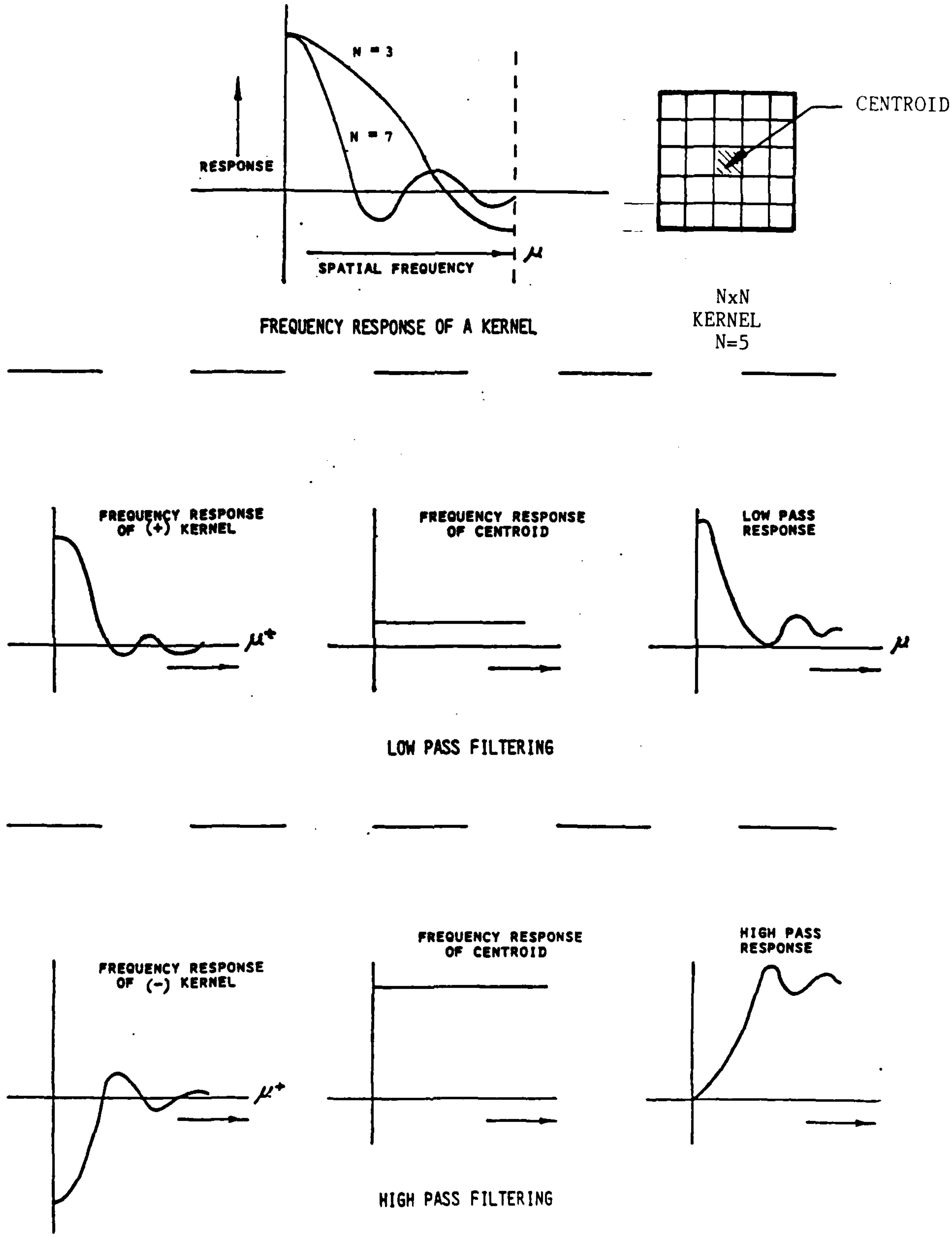


FIGURE 3-7 CONVOLUTION RESPONSES

The one dimensional frequency response of the kernel approximates the function:

$$f(\mu) = \frac{\text{Sin}\,\mu}{\mu} \tag{3-9}$$

Where is the spatial frequency. Larger values of N causes the first horizontal intercept of the function to move closer to the vertical axis for a narrower response.

The frequency response of the centroid can be thought of as an all-pass unfiltered response with a magnitude equal to the multiplying constant or variable. By choosing larger values for the centroid multiplier, a frequency response can be produced which contains a percentage of the unfiltered image. The result is called a mixed frequency response. The mixing ratio is defined as:

$$\text{Mixing Ratio} = \frac{\text{Smallest } F(\mu)}{\text{Largest } F(\mu)} \times 100 \tag{3-10}$$

(The smallest amplitude of frequency response divided by the largest amplitude of the response.)

It must be remembered that the spatial frequency is defined as the number of samples on each horizontal line and that the Nyquist sampling criterion requires that the maximum frequency be limited to one half the sampling rate.

During convolution those kernels which overlap the vertical and horizontal image borders present a notable problem because

these kernels contain "pixels" outside of the image. If these pixels are included in the calculations, the image edge kernels would create objectionable artifacts in the filtered image. The problem becomes most noticable as N increases. A solution is to treat these "border" pixels as if they extended indefinitely both horizontally and vertically. Therefore, border kernels that would have contained odd pixels that are filled with image pixels.

Every output pixel (processed by convolver) results from the summation of a kernel value and a centroid value. In producing the kernel, the hardware would breakup the kernel into simpler units called vertical sums (Vsums) and horizontal sums (Hsums). A Vsum is the sum of N vertical pixels and an Hsum is the sum of N horizontal Vsums.

Vsums are calculated by taking the difference between the incoming pixel (new) and a pixel that occurred N lines previously (old) and then adding this difference to the previous (old) Vsum.

The hardware for implementing the Vsum algorithm is shown in Figure 3-8. It consists of two memories (shift registers) one of which is N lines long with the other one line long, a subtractor, and an adder connect as a one line delay accumulator.

The Hsum processor is also shown in Figure 3-8. It calculates the difference between the new Vsum and the old Vsum and then adds this difference to the previous old Hsum. The hardware consists of an N pixel delay shift register, a subtractor, and an adder connected as a one pixel delay accumulator.

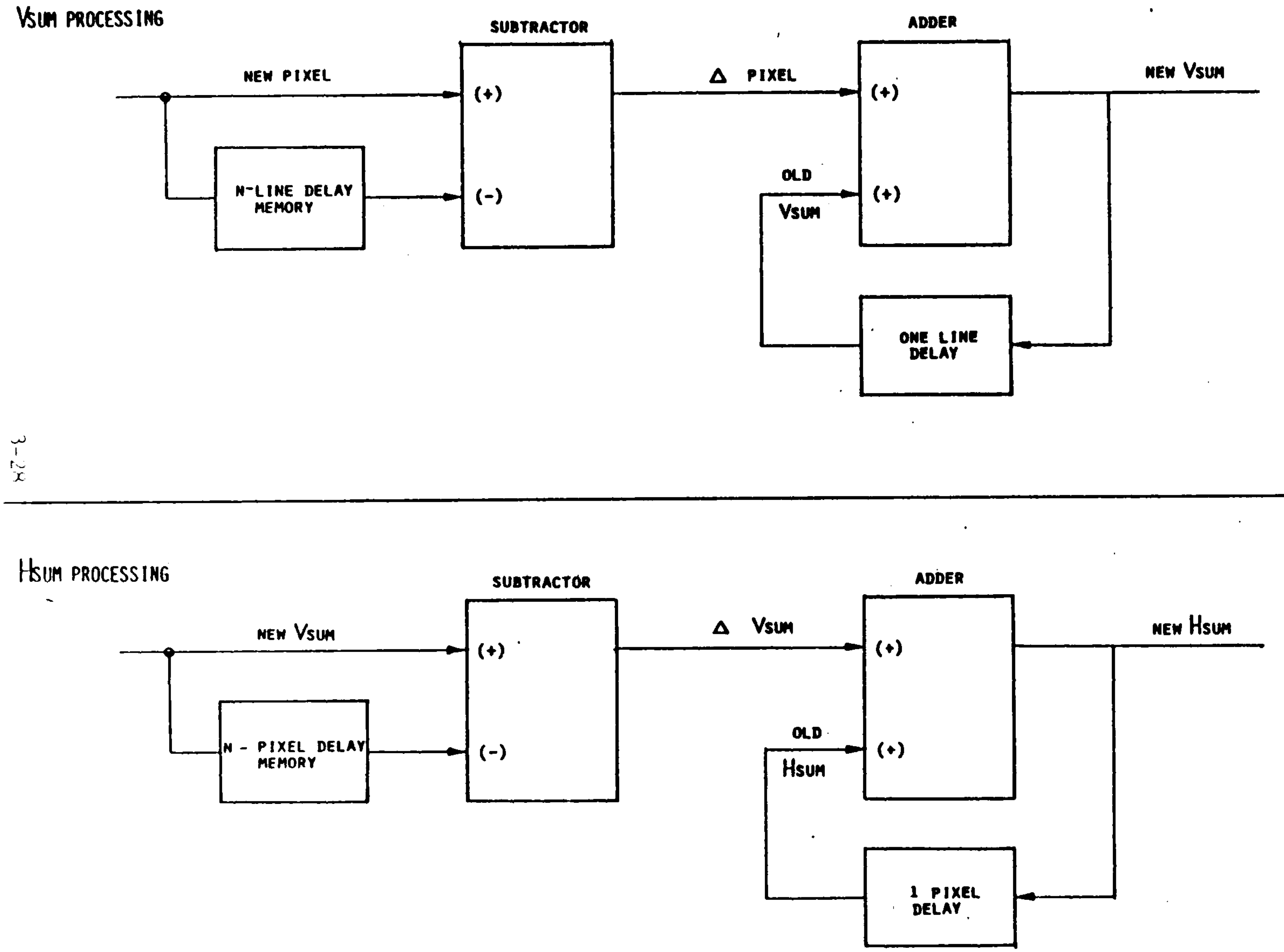


FIGURE 3-8 CONVOLUTION BLOCK DIAGRAMS

3.1.6 Whole Fiche Scanner Summary

Overview

Previous sections have discussed details of the scanner. In most cases, the information above is applicable to either a single image scanner (i.e. servo controlled scanner head with a single linear EO array) or the WFS. The MITS I demonstration system used the single image scanner.

But the single image scanner suffers from two deficiencies in the MITS II application:

1) Cannot achieve the required system throughput because of pixel time constraints of the EO sensor.
2) Cannot easily overcome the problem of cropped image borders caused by displaced and skewed images on the master fiche.

The WFS does not easily accomodate the image packing concept first addressed by NOSC in 1974. The MITS I demonstration proved the concept to user's satisfaction but that system encountered the problem of cropped images. The only significant benefit of image packing is the reduced cost of film for the facsimile recorder. We judge that benefit to be too small when compared to developmental difficulty and risk.

Figure 3-9 illustrates the microfiche format. The header area of the fiche is eye readable and requires a scanner resolution of 200 lines/inch. The image area is a 24 X reduction and requires a resolution of 4800 lines/inch. The image area is configured with

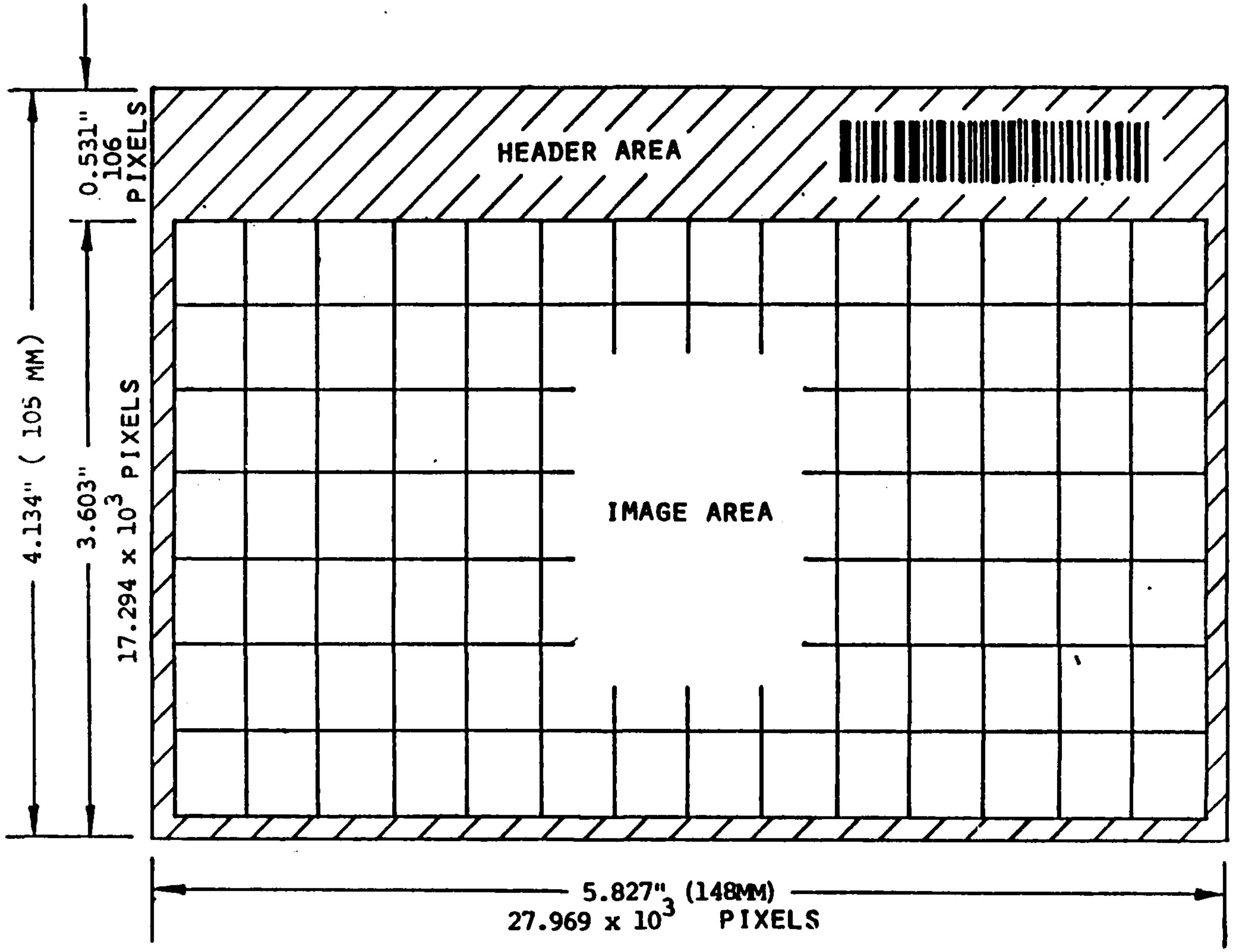


FIGURE 3-9 MICROFICHE FORMAT

images in 7 rows and 14 columns for a total maximum of 98 images/ fiche.

The personnel record formats are shown in Figures 3-10 and 3-11. Note that a person's record is filled by adding images to a particular row. Many of the records contain blank images. In fact the average fiche contains less than 50 document images. Because of the way that the master fiche is updated, we know that blank images will always be at the end of the rows. In other words, if a particular row contains only three images, they will be located in the first three locations on the row and the following eleven image locations on that row will be blank. This is very important a priori information.

The record format was one factor in our selection of the vertical scanning direction. The other main factor for this choice is the dimensions of the fiche itself. Since we want to have a scanning head comprised of contiguous pixels, we chose the shorter dimension (105mm). The final reason for vertical scanning is that we also wish to scan (and automatically reproduce) the header area.

Scanning the fiche in the vertical direction necessitates image rotation somewhere in the process. The 2D Compression algorithm may be more efficient with normal horizontal data. In any event, the remote site recorder needs the data presented in the normal fashion. See Figure 3-12 and Section 3.8.3 below. The logical place to perform the image rotation is in the compressor. There, the input buffer memory could be used to perform the rotation.

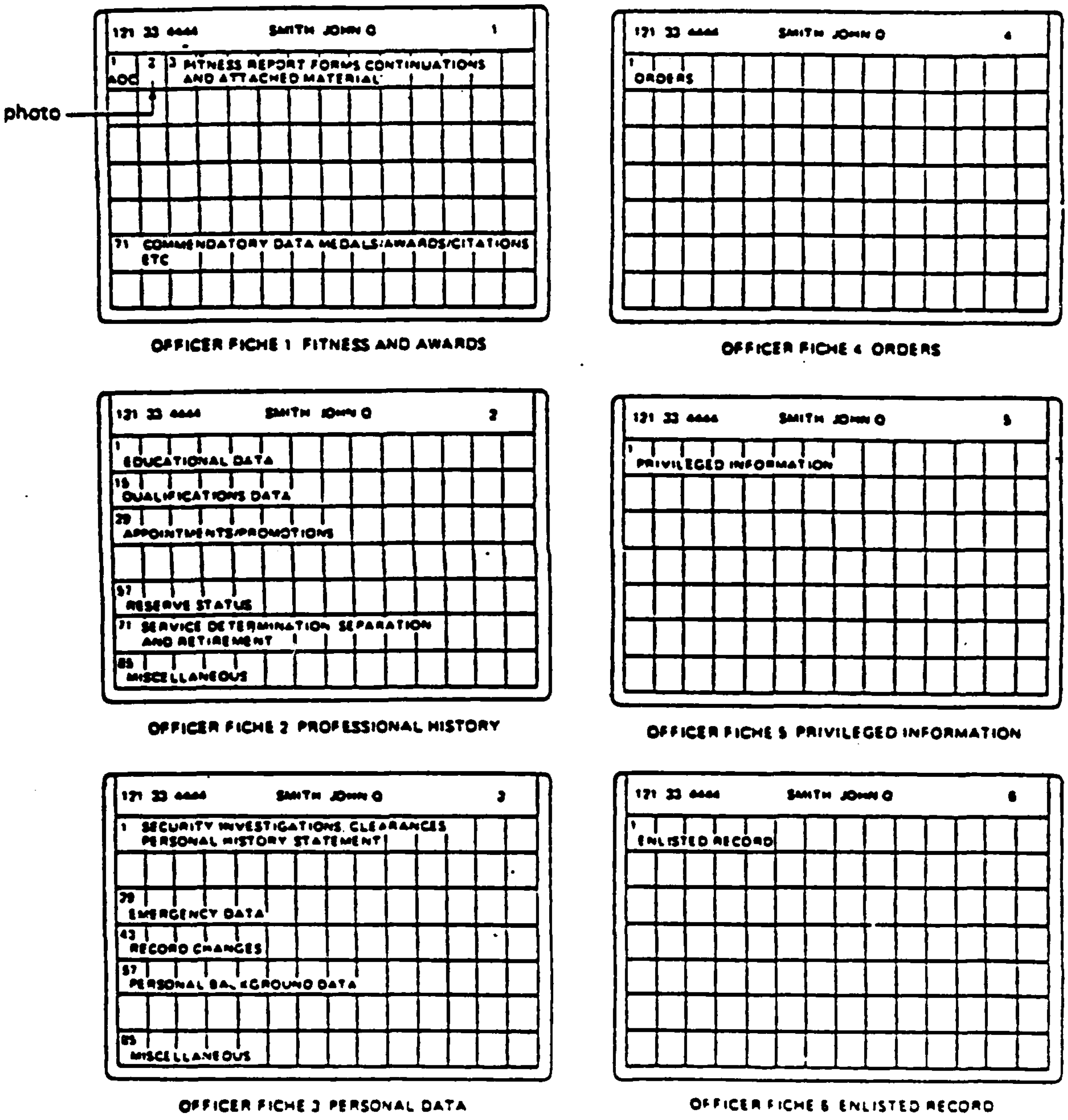
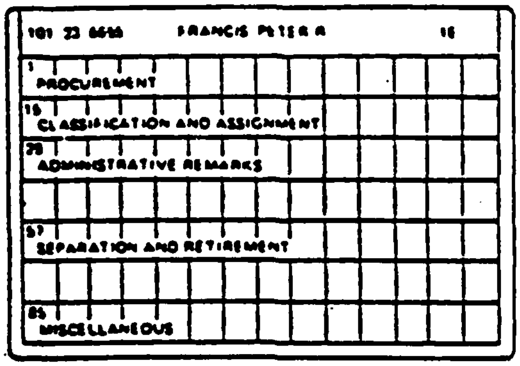
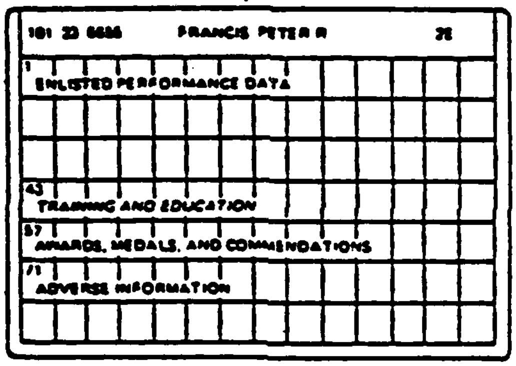


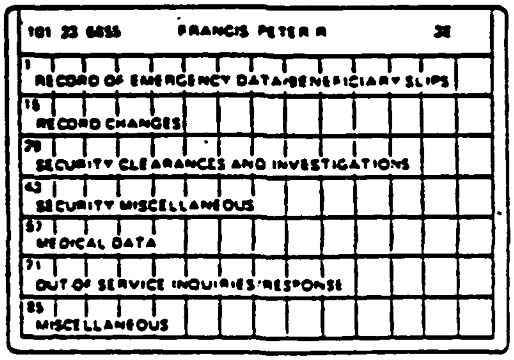
FIGURE 3-10 RECORD FORMATS FOR OFFICERS



ENLISTED FICHE 1E PROFESSIONAL SERVICE HISTORY



ENLISTED FICHE 2E
PERFORMANCE EVALUATION AND TRAINING DATA



ENLISTED FICHE 3E PERSONAL DATA

FIGURE 3-11 RECORD FORMATS FOR ENLISTED PERSONNEL

Pixel Size

The image area has a vertical dimension of 91.52mm. This distance must be divided into 17.294×10^3 pixels to achieve the resolution required. Therefore:

$$\text{Pixel Size} = 87.5 \times 10^{-3}\text{m} \div 17.294 \times 10^3 \text{ pixels}$$
$$= 5.06 \times 10^{-6}\text{m/pixel}$$
$$\text{or } 5 \text{ microns} \qquad (3\text{-}11)$$

Thus, each fiber in the fiber optic head has a dimension of 5 microns. Note that we earlier described how the fibers are coupled to the photosites on the Diode Arrays or CCDs. The photosites can be larger than the fibers but they cannot be smaller than the fibers.

In the header area, the same calculation would show that the pixel size is approximately 120 microns.

WFS Block Diagram

Figure 3-12 shows the block diagram for the Whole Fiche Scanner. It illustrates the scanner operation from the fiber optic image input to the output clipper. Details of the various parts were described above.

The 17K contiguous pixel fiber optic bundle is divided into subribbons which are coupled to individual linear EO arrays. If 2048 pixel arrays are used for scanning the images, nine (9) would be required. An array of at least 128 elements is required for the Header area.

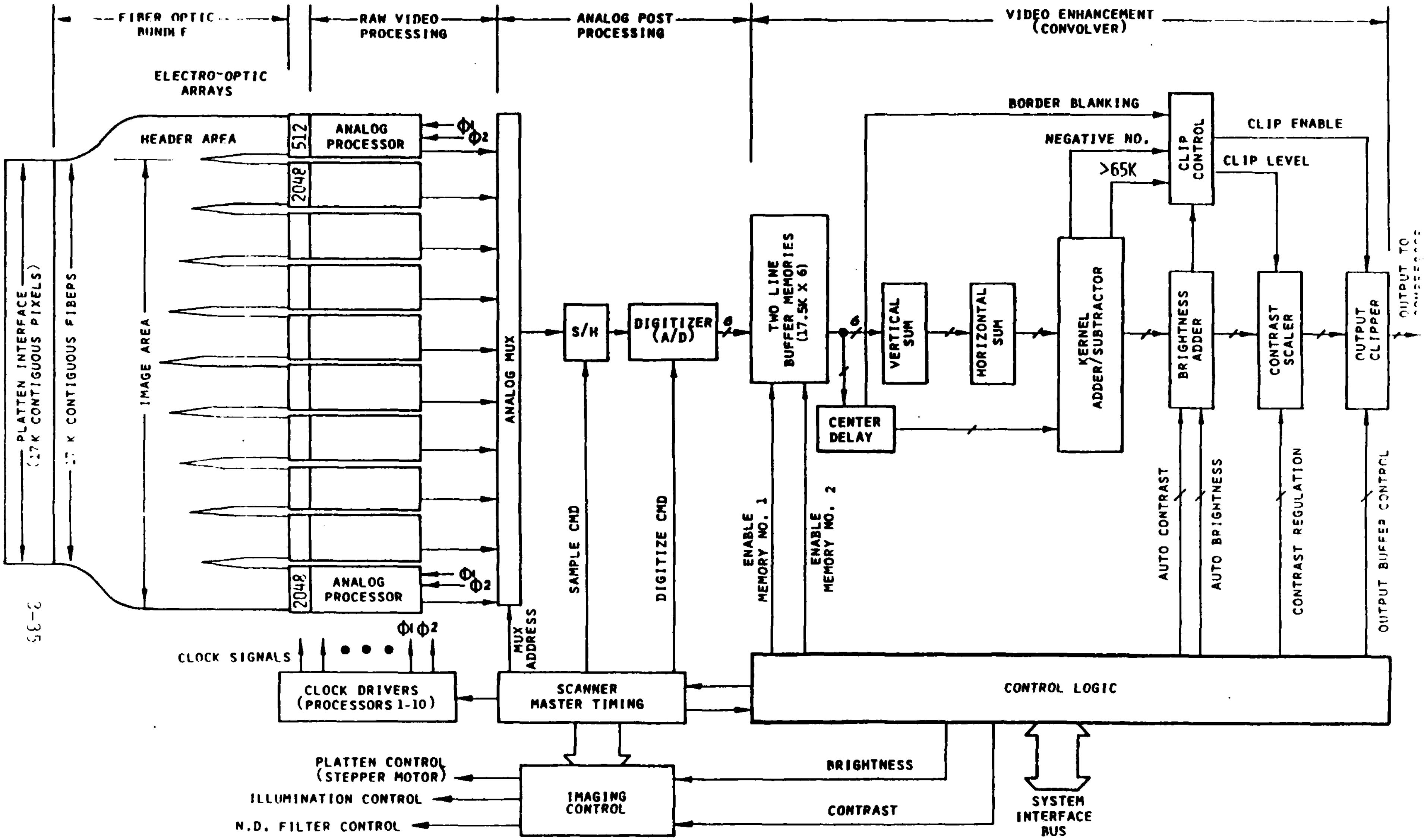


FIGURE 3-12 WHOLE FICHE SCANNER BLOCK DIAGRAM

The parallel video processors provide the scanner with the capability to satisfy the throughput requirement. The electronics which follows the video processing is high speed logic.

Timing Considerations

If the WFS is to be practical, electronic timing or processing speed must be addressed. The present state of the art establishes the following limitations:

a) Integration Time - The range for integration time is 1 to 8 ms. Below 1 ms, the intensity of light becomes too high. Above 8 ms, dark current becomes objectionable. Optimum is 3-4 ms. Also depends upon quantum efficiency (QE) and charge transfer efficiency (CTE).

b) The maximum rate for a 6 bit flash A/D converter is 20 MSPS (50 ns conversion time).

c) The absolute maximum MUX speed is 50 ns.

d) Minimum pixel time for most arrays is 200 ns.

e) The absolute maximum convolver speed is 100 ns. Higher speed logic would be prohibitively expensive.

Simple calculations will reveal how near to these limitations the WFS electronics must perform. First, consider integration time:

$$T_i = \frac{60\text{s}}{28{,}000 \text{ lines}}$$

$$= 2.14 \text{ ms/line} \qquad (3\text{-}12)$$

Next, the A/D conversion time and MUX time can be calculated. Assuming 1 ms to MUX and convert the video signals during the

dwell of the stepper for one line of pixels (17,500 pixels), the time available per pixel is:

$$TM\&D = \frac{1 \times 10^{-3} s}{17.5 \times 10^{3} \text{ pixels}}$$

$$= 57.1 \times 10^{-9} s/\text{pixel}$$

$$= 57.1 \text{ ns/pixel} \qquad (3\text{-}13)$$

Lastly, the convolver time can be calculated. It is obvious from eq. 3-13 that if a stepper motor drives the film transport (with 1 ms/line dwell time), there would be insufficient time to perform the convolution. In other words, the full 2.14 ms/line scan time is required to satisfy the 100 ns maximum convolver speed. In this case the convolution time is:

$$Tc = \frac{2.14 \times 10^{-3} s}{17.5 \times 10^{3} \text{ pixels}}$$

$$= 122 \times 10^{-9} s/\text{pixel}$$

$$= 122 \text{ ns/pixel} \qquad (3\text{-}14)$$

In order to utilize all of the available per line scan time for the convolution, a buffer memory must be provided. The buffer memory stores two lines worth of the digital data (17.5 K X 6 each line). The bottom line in the stack is written in by the A/D (1 ms). The top line on the stack is read out by the convolver during its process operation.

Handling Blank Images

We know a priori that if the scanner encounters two blank images in any row, all succeeding images in that row will also be

blank. What other information is there, that would be useful in handling blank images?

Discussion with the compression study contractor, revealed that other valuable information is available, Ref 18. There is an index listing in the MPRS computer. This information is normally used in the semiautomated process to update (change) the master fiche records. The index contains information such as:

1) SSN and fiche numbers for each record.

2) Number of documents (images in each file).

3) Content and number of trailer fiche.

One scheme for using this information for scanning is via the transaction microcomputer's "Pull Record Request". In other words, when the MPRS computer receives the request, it would not only acknowledge the request (Record Exists) but it would also query the record index and feedback to the microcomputer this valuable information. The microcomputer would pass this data on to the main process controller (minicomputer). Finally, the minicomputer would tell the scanner where the blank images are on each fiche.

The logical place to use these blank image flags would be in the compressor section of the scanner. Here, the compressor could simply insert a short message into the data stream which gives image corner addresses (pixel addresses) and a "blank image" word. Recall that each image represents about 4.5×10^6 bits of data (Eq.3-1). If the "blank image" message were to use 450 bits (quite a lot), the "blank image" data compression ratio would be 10,000:1.

Implementation of this scheme would require adding a subroutine to the MPRS computer to access the record index data. We do not know how difficult or even if this would be practical. If it is, however, the use of this existing information would be a great benefit to MITS II. The "image data" quantity is vastly reduced. If this or a similar scheme is not practical, the other choice is to let the compressor process all images (real or blank) with its standard algorithm. In this latter case, the blank image compression ratio is estimated to be 50:1 or higher. See reference 18.

Summary

The primary features of the WFS are:

a) High scanning speed because of parallel processing (overcomes pixel time constraints)

b) Simple one dimension film transport (lower cost, higher reliability mechanics)

c) Solves problem of image detection and centering

d) Output facsimile can be exact duplicate of input fiche including eye readable header (eliminates the need for all operator keystroking)

e) Built-in realtime image enhancement

The benefits of the WFS are:

a) Speed

b) High performance (no lost image data and high legibility)

c) High reliability (simple mechanics and optics)

d) Operator Simplicity (just load fiche in stack loader)

3.2 Image Data Compression

As stated above, our statement of work omits the requirement for a rigorous analysis of image data compression for MITS II because the Navy has another contractor addressing this technical area. However, we could not completely ignore data compression in our analysis because data compression techniques do impact upon other elements of the overall system.

These other considerations include:

a) How the image data is presented (fed) to the compressor electronics so that it would be compatible with the compression algorithm.

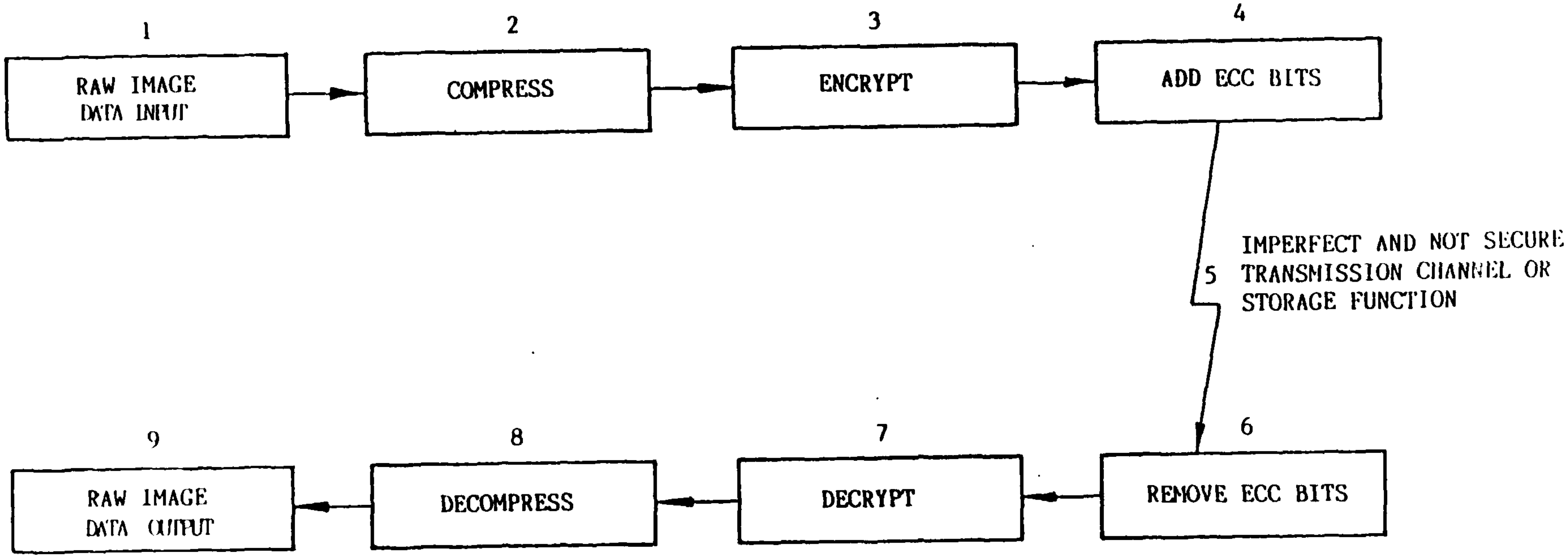
b) The effect of data encryption if used for security requirements.

c) The effect of error correcting codes (ECC) used in data storage (disk) and in the satellite link.

d) The remote site data decompression and the output format of the data fed to the fiche recorder.

Figure 3-13 is from reference 19. It shows the sequence in which compression, encryption and error correction must be performed. If the Navy believes that encryption is not necessary or that security could be maintained by keeping the special compression/decompression algorithms secret, the requirement for encryption might be eliminated. In any event, error correction still applies in both data storage and the communications link.

Because of these facts, optimum compression/decompression algorithms may not be possible. For example, one may choose to



NOTE: FROM REF. 19

FIGURE 3-13 COMPRESSION, ENCRYPTION, ERROR CORRECTION SEQUENCE

compress the image data into suboptimum size blocks so that uncorrectable errors would cause the loss of only a small part of the image. In the case of the ECC with the satellite link, the communications supervisor (in the interface unit microprocessor) could order a retransmission of the erroneous packet of data. Recovering from uncorrected errors encountered in storing the data on the disk is not possible. But the error rate for data storage is much less than in the transmission link.

The main point to the discussion above is that the final design of MITS II must be closely coordinated in the areas of compression, encryption and error correcting coding. This information was confirmed in discussions with the Navy's compression investigations contractor, reference 18.

3.2.1 Image Data Input/Output of Compressor

The description of the WFS above shows how the enhanced, clipped (1 bit/pixel) data is presented to the compressor. The compressor accepts (serially) one vertical line of data from the column of seven images, and stores sufficient data for its 2-D run length code compression algorithm. Part of the process should include output image rotation, data block formatting, and block data buffering. The output data buffer will store a reasonably large set of compressed image data bit-packed into 16 bit words (32K-64K words). This block of compressed data would be output to the process controller (minicomputer) via a block mode DMA transfer. See description of process contoller in Section 3.3 below.

The reason for the image rotation requirement, is to prepare the data to be compatible with the recorder at the remote site. The reason for the output data buffer requirement, is to satisfy overall system throughput requirements.

3.2.2 Image Data Input/Output of Expander

The expander electronics will functionally fit between the remote site minicomputer and the fiche recorder. Depending upon its size and power requirements, it might be physically located in the recorder cabinet.

The expander accepts block mode DMA transfers from the minicomputer, performs the expansion and outputs the image data to the recorder's image storage buffer. Note that the recorder prints the fiche on an image-by-image basis. Images are printed from top to bottom of the columns.

3.3 Scanning and Data Transmission Process Controller

This part of the MITS II analysis directly relates to statement of work items 9 "Improved system reliability and maintainability" and 5, "Improved system operating procedures ...", and indirectly relates to item 6, "Improved system software ...". The central site process controller also has critical impact upon total system performance.

The process controller is the nerve center of the MITS process. In our system level design, we used a conventional process control design approach, i.e., the selection of a minicomputer system for the process controller. The analysis consisted of the following steps: a) Defining functional requirements, b) Defining interface requirements, c) Defining software requirements and d) Analyzing various minicomputers to find an affordable match to the requirements. The sections below summarize the results of this work.

3.3.1 Functional Requirements

The central site process controller is a commercially available minicomputer system which is configured to perform the following functions:

a) Provide supervisory control of the image scanning and data transmission process.

b) Provide temporary storage of one fiche worth of compressed image data.

c) Format and report record ID (SSN and fiche number) to the microcomputer system for audit trail input.

d) Provide realtime system test and system status reporting.

e) Synchronize throughput data rates of the scanner and the satellite data link.

f) Provide facilities for software maintenance and revision during maintenance periods.

g) Provide facilities for system hardware maintenance and repair during maintenance periods.

Figure 3-14 shows the configuration of the central site minicomputer system. Each block shown connected to the bus is a commercially available plug-in module. All other solid blocks are also commercially available hardware. In other words, the minicomputer system contains no "special purpose" MITS specific hardware elements. MITS specific features are contained in the process control and test software.

The software operating system would be a compact, realtime single user operating system with foreground/background modes. Foreground programs are used for process control. Background programs are used for system testing, monitoring and status reporting. Application programs are developed in a high level structured programming language which is compatible with the realtime operating system. This structured and self documenting programming environment simplifies future software maintenance.

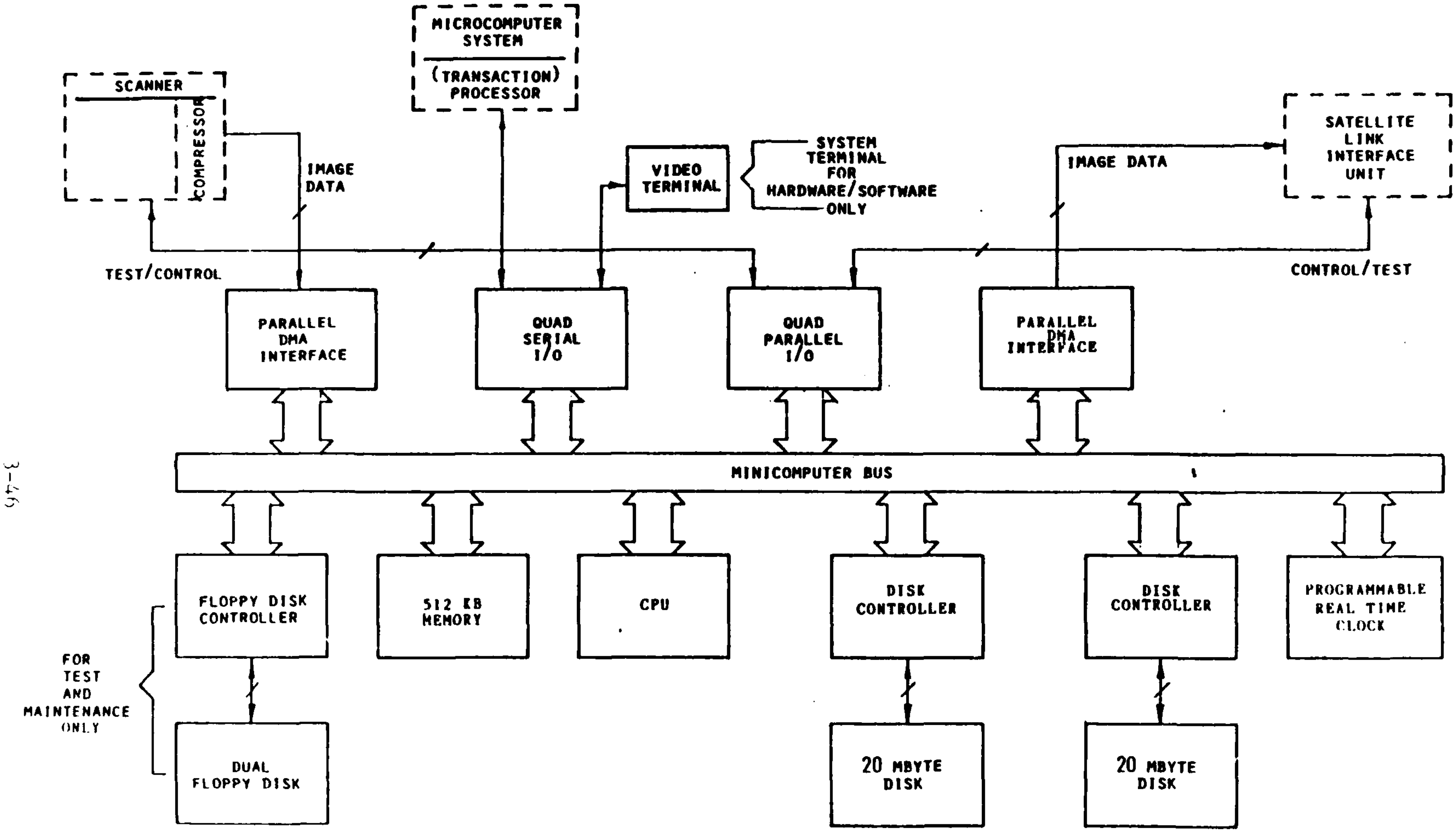


FIGURE 3-14 CENTRAL SITE MINICOMPUTER

3.3.2 Functional Description

Image data from the compressor is input to the minicomputer via an interface in block mode DMA to a restricted block of memory. The processor adds header and trailer data to the block and stores it on one of the two disks.

When the 64KWord buffer memory in the Satellite Interface Unit is ready to receive a new block of image data, the processor directs a block mode DMA transfer from the disk to the satellite link via a second dedicated DMA interface module.

The processor then services other system equipment such as another block input of image data from the scanner. It will be shown that the image data buffering (to disk) and throughput synchronization process will use one half of the processor's bus time. The other half is available for process control, test and reporting operations. See section 3.3.4.

Included in the minicomputer system are a system terminal and dual floppy disk. Neither of these are required during record scanning and data transmission. They are used during hardware/software maintenance and repair or for new software installation. In other words, the operators of the MITS II will have no interface (keystroking) with the terminal of the minicomputer system.

A serial RS-232 interface provides communications between the minicomputer and the microcomputer used for transaction processing. The micro uses the link to tell the mini the SSN of upcoming records. The mini uses the link to confirm SSN records,

report process status (i.e. stack loader empty) and report system failures (i.e. scanner down, call maintenance).

3.3.3 General Characteristics

The system level minicomputer was designed with the following criteria:

a) No special purpose MITS specific hardware.

b) Commercially available general purpose minicomputer.

c) Conventional bus architecture.

d) Image data handling and buffering is to use no more than one half of bus time.

e) Two large capacity disks for redundant reliability.

f) Process control, supervision and test to use efficient realtime operating system.

g) No direct operator intervention required.

h) Low cost.

i) High reliability.

3.3.4 Hardware/Software Description

Our system design (recommendation) for the process controller calls for a Digital Equipment Corporation Q Bus minicomputer. With the configuration shown, it would have performance roughly equivalent to the PDP 11/44; See Reference 20. A primary consideration was the speed of block mode DMA transfers of the image data; See Reference 21. The parallel interface modules (DRV11-B) require approximately 1.6 microseconds to transfer one

16 bit word - 625 KWPS. We want this speed to be high compared to the system choke point data rate of the satellite link.

Earlier, the data rate goal for the satellite link was established as 1.47 MBPS. This rate is equivalent to approximately 92 KWPS (16 Bit Words). Thus, if the satellite interface unit contains an elastic buffer, that buffer can be filled at the maximum output rate of the minicomputer and the bus is busy with this transfer for 1/6 of its time. A similar portion of the bus time is required for input of the image data from the compressor. A third 1/6 period is needed for transfer from memory to the disk.

Thus, the functions of receiving, storing and outputting the image data keeps the bus busy for approximately one-half of the available time. The other half is available for other service such as process control, status monitoring, fault reporting and process reporting.

The hardware (See Reference 22) in the minicomputer consists of:

a) Cabinet

b) Chassis with Power Supply, 4x9 Slot Box (BA11-SA)

c) CPU Card (LSI 11/73)

d) Memory Card, 512 KB (MSV11-PL)

e) Quad Serial I/O Card (DLV11-J)

f) Quad Parallel I/O (DRV11-J)

g) Parallel DMA Interface, 2 each (DRV11-B)

h) Programmable Realtime Clock (KWV11-C)

i) Dual Floppy Disk (RXV21)

j) Terminal (VT102)

k) Dual Disk Controller (Emulux)

l) 20 Mbyte Disk, 2 each

It is conservatively estimated that the cost of this hardware would be $25,000.

The operating system and higher level structured software consists of:

a) RT 11 Operating System (QJB46-DZ)

b) Micropower Pascal (QJ029-XXQ)

This software, with highest level support license, would cost approximately $2,800.

3.4 Satellite Link Interfaces

The satellite link for MITS II is the "choke point" in the system. This fact is true because the system designer is restricted by the compressed image data rate of 1.544 MBPS. In addition, downtime of this link directly affects system availability and record throughput.

The required volume for MITS II is 50,000 document images in a 20 hour day. By comparison the MITS I demonstration system handled a volume of 22,500 images over a six month period. See Reference 23.

These facts illustrate the criticality of the satellite link in MITS II performance. The system designer has no control over the performance of the satellite link service itself. The service will be leased from a commercial provider; see Reference 24. That service, from whatever source, will probably demonstrate very high availability and very low error rate. Thus the system designer's task is to design the interfaces to the link such that the overall system achieves maximum utility from the link.

3.4.1 Functional Requirements

Sending End Requirements

Figures 3-15 illustrates the interface to the satellite link at the central site. At the sending end these functions include:

a) Accepting the compressed image data from the mini-computer system (16 bit parallel, 625 KWPS).

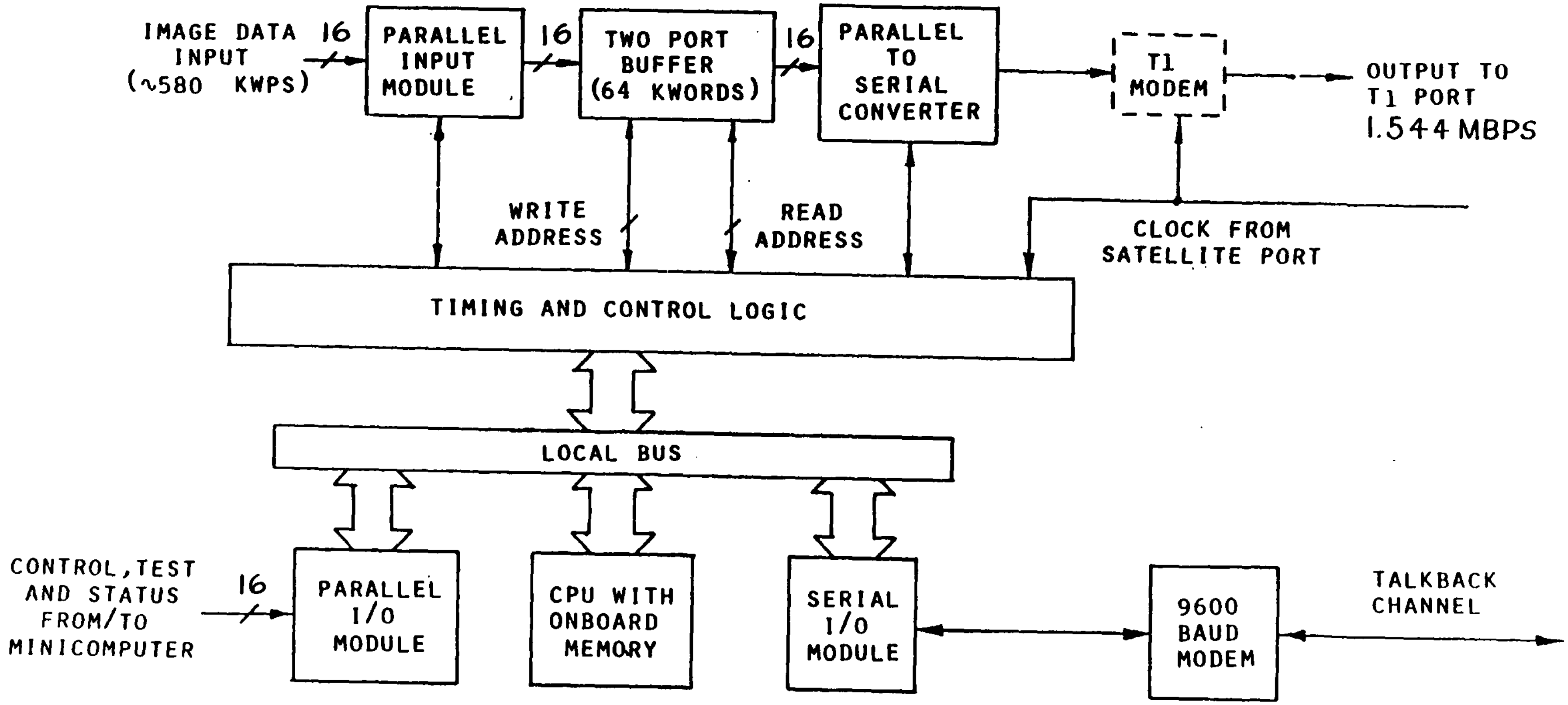


FIGURE 3-15 CENTRAL SITE COMMUNICATION INTERFACE

b) Providing an elastic two-port buffer (approximately 64K words).

c) Performing parallel to serial data conversion.

d) Interfacing to a modem to the T1 port (output clock provided by satellite service).

e) Providing communications link control and supervisory signals via the talkback channel.

f) Handshaking with the central site minicomputer (Main Process Controller) with a variety of control, status and test messages.

Each function is needed to achieve maximum link utility.

The parallel input module provides compatible interface to one standard 16 bit parallel I/O port of the minicomputer for the compressed image data. Its electrical characteristics are defined by the minicomputer's I/O port.

The two port data buffer permits input time division. In other words, the buffer is filled (written into) at the maximum output rate of the minicomputer; this input rate will be approximately 625K words per second. The buffer will be emptied (read out) at the lower rate of approximately 92 KWPS. By means of this technique, the minicomputer needs only service (feed) the link interface with less than one sixth (1/6) of its time. And the rest of its time is available for servicing other equipment in the overall process.

The parallel to serial converter can be a conventional pair of shift registers with input and output gating.

The T1 Modem accepts the image data stream. It outputs the digital signal in accordance with the T1 specification. A synchronization clock signal is provided by the satellite link.

The interface unit includes a local microprocesser controller. Control, test and status reporting communications between the interface unit and the central site minicomputer is via a separate parallel I/O port. The sending end interface unit communicates link supervisory information to and from the receiving end interface via the serial I/O module and the 9600 baud modem through the talkback channel.

Receiving End Requirements

Figure 3-16 illustrates the interface at the receiving end. Its functions include:

a) Interfacing to a link modem to the T1 port.

b) Serial to parallel conversion.

c) Providing an elastic two port buffer.

d) Outputing compressed image data to the remote site minicomputer system.

e) Communicating link control and supervisory signals via the talkback channel.

f) Handshaking with the minicomputer (Remote Site Process Controller) with a variety of control, status and test messages.

For the image data stream, all functions are the inverse of the functions at the sending end.

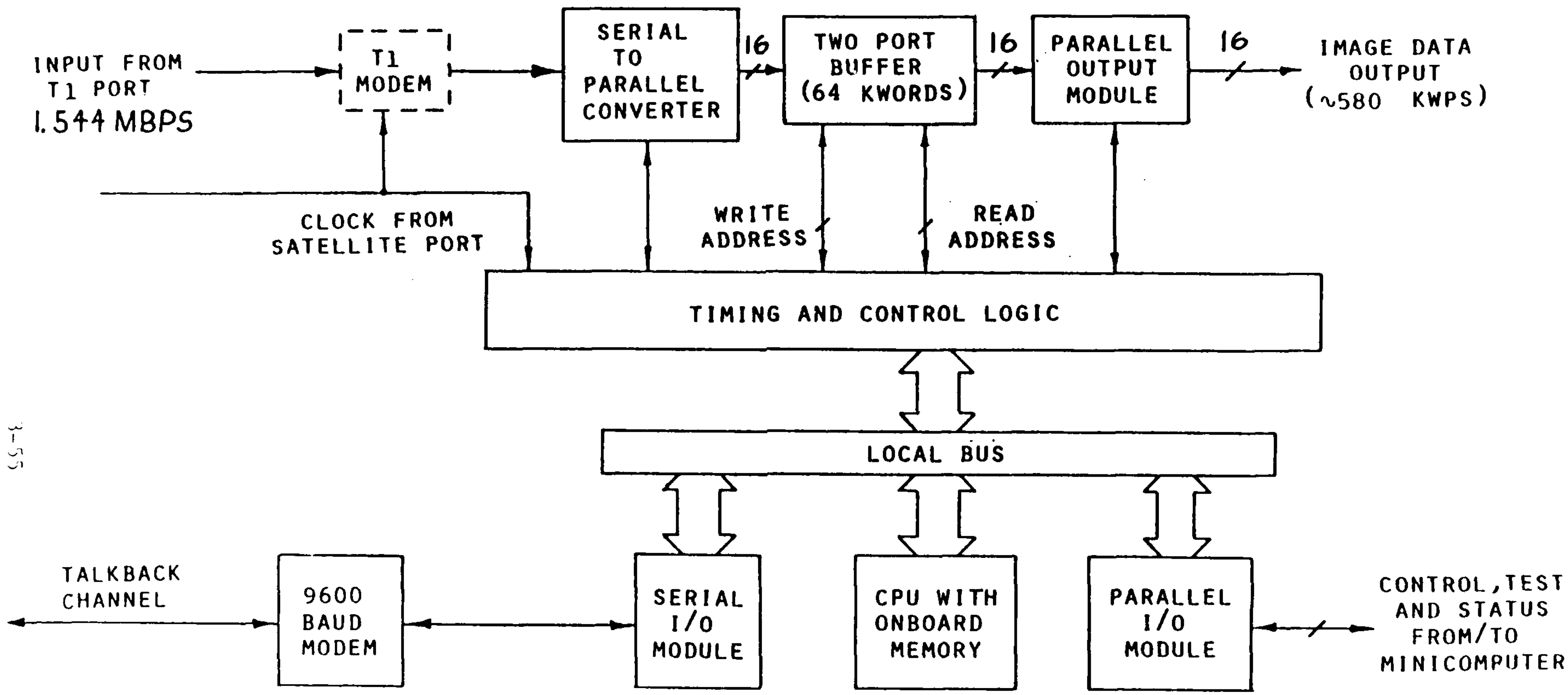


FIGURE 3-16 REMOTE SITE COMMUNICATIONS INTERFACE

3.4.2 Summary Functional Description

The minicomputer's disk at the central site stores the compressed image data for one fiche. It hands-off a block of this data to the interface at its maximum rate of approximately 625 KWPS. Block data transfers are possible because of the elastic buffer within the interface unit. See Figure 3-17.

The microprocessor within the sending end interface keeps track of the communications process, the status of its buffer and the status of the receiving end process. The results of this communications supervision is fed back to the central site minicomputer by means of status messages.

In normal operation, the most important message is "ready to receive the next block of image data". Other messages might be requests such as: "resend the last block", "not ready", and "stop".

Test subroutines in the interface microprocessor's ROM would provide for self test of the local interface and the end-to-end communications link. Status and test messages from the minicomputer (main process controller) to the remote site equipment is passed through the interface via the 9600 baud talkback channel. This channel is also used to feedback status and test information from the remote site.

In summary, the satellite link interface units provide:

a) Electrical interface to the satellite ports

b) Image data communications between the two minicomputers systems (in blocks)

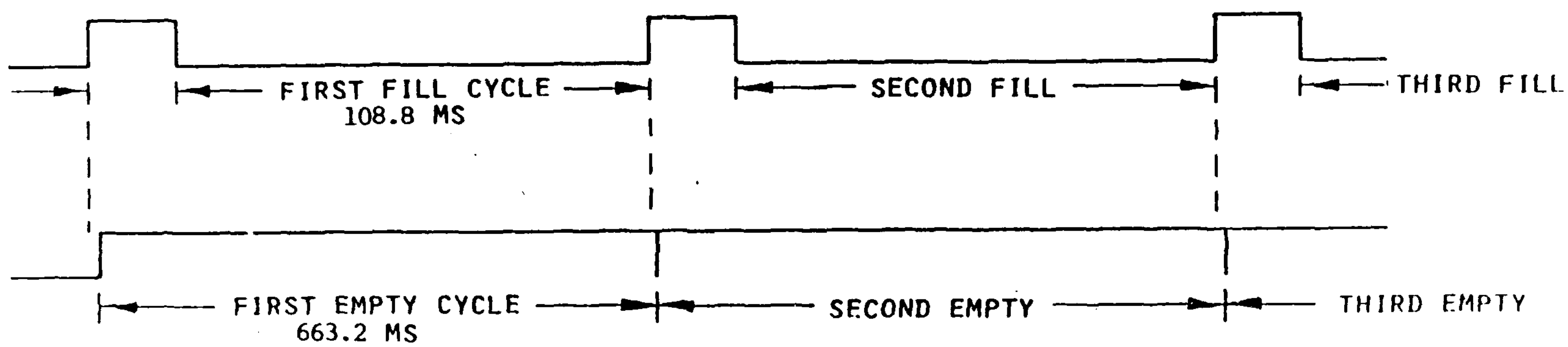


FIGURE 3-17 ELASTIC BUFFER TIMING, CENTRAL SITE

c) Superisory control of the communications link

d) Self test of the interface units

e) Self test of the communications link

f) Overall system test and status communications.

3.4.3 Hardware Requirements

In our survey, we could find no commercially available hardware which would fully satisfy the interface functional requirements for MITS II. There are a number of manufacturers who presently supply digital interface units generally referred to as multiplexers.

This general class of equipment accepts a number of digital input channels, at various baud rates, and multiplexes them into a form acceptable to the T1 digital standard. The maximum input rate discovered to date is 512 KBPS; see Reference 25. Other supplier's multiplexers usually top out at 56 KBPS. The reason for this lack of commercially available equipment is because the digital T1 satellite service is so new. There are few, if any, 1.544 MBPS commercial applications.

Even if a commercial multiplexer could be adapted for the higher input rate, special additions would be needed to provide the elastic data buffer and minicomputer interface. Standard multiplexers normally accept serial data from a dedicated source.

Standard communication protocols are used in standard multiplexers. Since the protocol messages are added to the data stream (instead of using a separate channel), overall efficiency

is quite modest. With some standards, overall efficiency is as low as 50%.

Because of these facts, the interface units for the MITS II application will need to be specially designed and built. This detailed design effort must be coordinated with the specific satellite service used with MITS II to assure compatibility. If American Satellite Corporation service is used for the first installation between Washington DC and San Diego, important information can be provided. At a meeting with Comtech Data Corporation, Reference 26, it was learned that Comtech provides the satellite modems for American Satellite Corporation. See data sheet in Appendix A.

Note that our MITS II system level design describes the satellite link communications as being between two minicomputer systems. As far as the high speed communication link is concerned, the data source and user is transparent. Because of this computer-to-computer communication, the SIC should find that McNamara's treatis on data communications bears study. See Reference 27.

Informal budgetary cost estimates from candidate suppliers of the interface units range from $12K to $50K per end for the hardware plus engineering development costs which range from $20K to $100K.

3.4.4 Availability Considerations

Because the satellite link is the system throughput choke point, very high availability should be provided by the interface

units. Our recommendation is for an availability goal of 0.990 for this equipment. Availability is defined as (Reference 28):

$$A = MTBF/(MTBF + MTTR)$$

The above availability would be achieved if the ratio of MTBF to MTTR is 100. In other words if the MTBF were 100 hours and MTTR were 1 hour the availability would be:

$$A = 100/101$$

$$= .9901 \qquad (3\text{-}15)$$

Note that a short MTTR requires modular construction, on-site spare modules, and standby trained repair technicians.

3.5 Reception and Recording Process Controller

The minicomputer at the remote site performs a similar function as the minicomputer at the central site. Its throughput requirements are identical. It has slightly less process monitoring burden (background programs). Because of these factors and the desire to have equipment commonality for provisioning spares and software considerations, we have chosen to have the remote site minicomputer be an exact duplicate of the central site system.

3.5.1 Functional Requirements

The remote site process controller performs the following functions:

a) Provide supervisory control of the data reception and facsimile fiche production process.

b) Provide temporary storage of one fiche worth of compressed image data.

c) Provide realtime remote site system test and status reporting.

d) Synchronize the throughput data rates between the satellite interface unit and the fiche recorder.

e) Provide facilities for software maintenance and revision during maintenance periods.

f) Provide facilities for system hardware maintenance and repair during maintenance periods.

Figure 3-18 shows the configuration of the remote site minicomputer system.

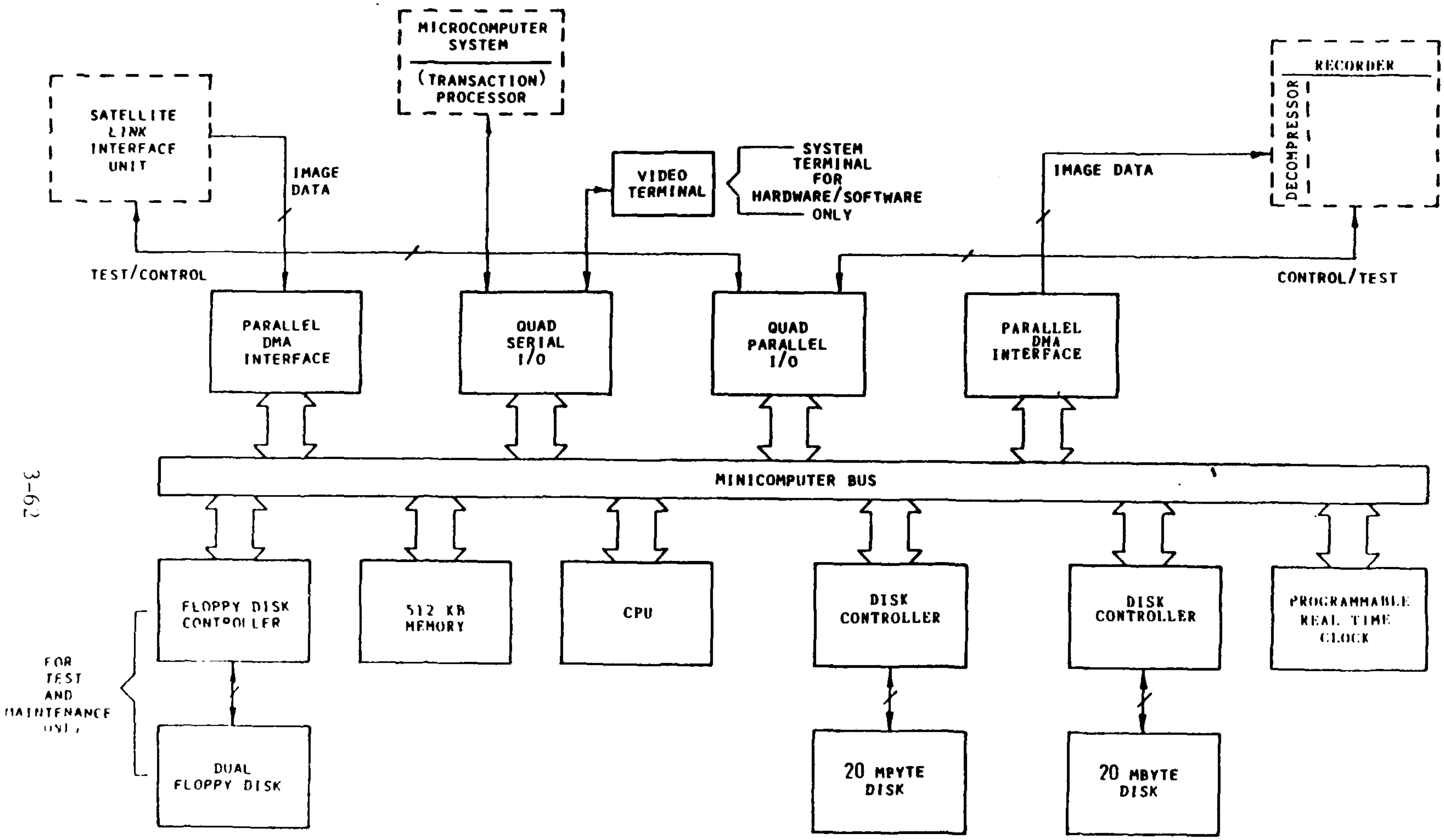


FIGURE 3-18 REMOTE SITE MINICOMPUTER

3.5.2 Functional Description and Hardware/Software

Image data from the satellite link interface unit is input to the minicomputer via a block mode DMA transfer to a restricted block of memory. The processor strips header and trailer data from the data block, stores these ID data in a separate memory location and stores the image data on one of the two hard disks.

When the decompressor electronics' buffer is ready to receive a new block of image data, the processor directs a block mode DMA transfer from the disk. These two actions synchronize the data rates of the satellite link to the recorder (decompressor).

Background programs provide self test, remote site status monitoring and status reporting via the RS-232 interface to the microcomputer.

The equipment's general characteristics are the same as at the central site. The hardware and software (except for application programs written in Pascal) is identical to that of the central site. The cost would be the same for the hardware (approximately $25,000). Operating System software and Micropower Pascal software would be the same as purchased for Central Site, i.e. no additional cost for remote site.

3.6 Main Process Software

The main process software investigations relates directly to statement of work item 6: "Improved System Software with assembly language code replaced by higher order language code". The reason for these investigations was a serious problem encountered during the MITS I demonstration. There, the applications software was written for a modified Multibus system in assembly language code stored in ROM. The contractor encountered numerous problems in debugging the software during system initialization and during later software modification. A suggested solution was to select a higher order, structured programming language. In this catagory are programming languages such as FORTH, C, PASCAL, ADA and others.

In our software investigations, numerous pros and cons were considered. First, ADA was evaluated for its suitability for MITS. DOD is requiring the use of ADA for all future strategic and tactical defense systems. MITS is neither of these. The use of ADA is very expensive. No commercial compiler has passed all of the ADA testing requirements. Very few programmers are experienced in the use of ADA. The beneficial features of ADA (structured, high level programmming, strict rules, etc.) are available with other languages at a much, much lower cost. It is our judgement that ADA is not suitable for MITS.

FORTH is a language first developed by astronomers for the control of tracking telescopes. It is a mature language and has found favor among some engineers in the machine tool and robotics industry. A larger number of programmers are experienced in its

use. Its use, however, has peaked. Engineers and programmers are tending to use other languages for new designs. We do not recommend the use of FORTH for MITS.

C is a language which has been used mainly in the academic community. The reason is the ease and cost of licensing. Non-profit organizations paid no license fee. Very few programmers and engineers in private industry are experienced in its use. Rumors in the computer industry are that the new AT&T will "soon" announce its new 32 bit microcomputer. It is claimed to use the UNIX operating system which supports C. If true, it will take a number of years before C is widely used and thus be cost effective. We do not recommend C for MITS.

PASCAL is the most mature, supported, and widely used higher level language for industrial applications. Most minicomputer manufacturers provide operating systems which support or are compatible with some version of PASCAL. PASCAL is the favored high level language for new designs. Because of its wide support and usage, there exist reasonably large libraries of subroutines for device controllers, timers, I/O handlers, schedulers, etc. These existing (and debugged) subroutines simplify the job of software development for MITS; thus the overall cost is reduced, technical risk is lower, and high software reliability is achieved.

The result of our investigation is the choice (recommendation) of Micro Power/Pascal. The reasons are:

a) It is compatible with the minicomputer's operating system, RT-11.

b) It is mature enough to have had most glitches patched.

c) Programmers in the imaging industry are experienced with its use. Many other programmers are also experienced in its use.

d) It is well suited to this process control application.

A short quotation from Reference 29 describes its characteristics:

"Micro Power/Pascal describes two system environments: a host system ... to create, build and test real-time application software, and a target system that runs the software.

The host system software includes an extended real-time Pascal compiler running under a subset of the RT-11 operating system ... A library of software modules for process synchronization, communication, scheduling, exception and interrupt handling, timer services, and device and file I/O in the target system makes it easier and faster to build your application.

... application program is created and linked with the appropriate run-time software in the development system. It is then transported to the target system by ... removeable storage media (i.e., diskette) or a read-only memory.

A symbolic debugging program runs in the development system ... to examine program variables and Kernel data structures and to control the execution of the application running on the target machine".

All of these features are needed for the MITS II. The initial development system can be either of the two (central or remote site) systems during contractor factory development. After installation and during the operating day the two machines are the

target (run the realtime programs) systems.

For software upgrading and maintenance a separate system could be used or either of the installed systems could be used as the development system during maintenance hours.

A valuable characteristic of any version of Pascal is its structure and self documenting features. This means that it is relatively easy for someone, other than the original programmer, to see what was done. Assembly language code, without extensive additional documentation, is impossible for others to follow.

3.7 Self Test, Status Monitoring and Reporting

The analysis effort and resulting system design in this technology area relates directly to statement of work item 9, "Improved system reliability and maintainability".

The MITS I demonstration was judged to have been "partially successful" in system status monitoring. Reference 1 states, "Failure detection and recovery procedures were very limited in scope and effectiveness. Toward the end of the demonstration, new kinds of failures were occurring regularly, especially in the output recorder. Since there was no remote system controller, failures at the remote site were often difficult to detect from the operator console at the central site. However, major component failures (at central site) were frequently detected and announced properly, with both an alarm bell and a message printed at the console. In all such cases, the operator was instructed to contact the system maintenance person for diagnosis and repair. The scanner, digital radio, and recorder all possessed error detection capabilities, but many error messages were not communicated to the system controller. Even at the device level, the error detection features were not comprehensive."

Our MITS II design overcomes all of these problems and is much more highly automated and operator friendly. This is possible primarily because of the use of more powerful main process controllers at both sites, and effective reporting via the microcomputer transaction processors. In other words, the people at both sites know "What's happening".

3.7.1 Requirements

As part of our analysis we have established the following requirements for self test, monitoring and reporting:

a) Each individual unit in the main process chain is to have fault localization sensors and circuits which are appropriate for its part in the process.

b) Detected faults or failures are to be reported in real-time (raise interrupt flags) to either or both of the minicomputer process controllers as appropriate.

c) The minicomputers shall each perform on line self test sub-routines (background programs).

d) The minicomputers shall invoke test routines on other units in the process (again background programs) at appropriate times. For example, testing of the scanner's electronics could take place while the fiche transport is returning to its pick up position.

e) Failure and status report messages shall be displayed on the minicomputer system terminals as well as being fed to the microcomputers via RS-232 channels at each site.

f) Remote site equipment status shall be maintained by the remote site process control minicomputer. It shall report this information back to the central site via the satellite link talkback channel.

3.7.2 Conceptual Description

A detailed design of the MITS II self test, monitoring and reporting features (hardware and software) is beyond the scope of

our effort. Those details are obviously controlled by the characteristics of the specific elements in the process. For example, the recorder will most likely have its own built-in self test and status monitoring features. In that case, there is no need to duplicate these features. Results are merely reported to the remote site minicomputer. Likewise, we are calling for (strongly recommending) that the satellite interface units include these capabilities for the end-to-end communications link.

Because the minicomputers have excess capacity (memory and speed) for their main purpose of process control, data buffering and synchronization, the excess can be used for very comprehensive system test and monitoring. These required features can be provided by software only. The same communication channels (parallel ports) that are used for process control, are used for testing communications. In other words, no additional hardware is required in the minicomputers.

AD-A141 040 MITS II (MICROFICH IMAGE TRANSMISSION SYSTEM) INVESTIGATIONS AND DESIGN ALTERNATIVES(U) ALEXANDER SYSTEMS CO SAN DIEGO CA D L ENDICOTT MAR 84 2/2

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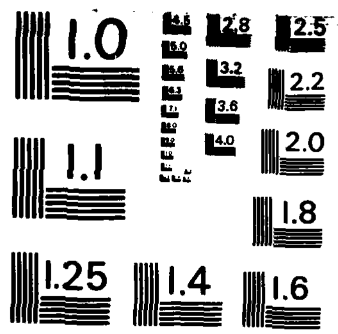


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

3.8 Microfiche Facsimile Recorder

The analysis effort for the recorder directly relates to statement of work item 4: "Methods for producing multi-grey level output microfiche (processing of grey level inputs, modulation of the writing beam, and film selection)". Our work was also guided by the overall objective of producing highly legible facsimile microfiche and other system constraints.

Our approach was to analyze the the characteristics of commercially available recorders to determine which, in our opinion, would be most suitable for the MITS II. Suitability involves a number of factors:

a) Throughput speed

b) Adaptability for bit mapped recording

c) Resolution

d) Proven basic product (Field use history)

e) Environment compatibility

f) Basic cost

g) Operator ease

h) Film type and processing

i) Multigrey level recording

At the same time that we were establishing overall system requirements, at the beginning of the project, we first addressed techniques for producing multigrey level output. All present COM recorders are bitonal (black or white) only. From those investigations we learned that either laser beam or CRT recorders could be modified to produce multigrey level output. But all responses were hedged with the caution that modulating the laser

beam or the CRT's Z axis would require complex redesign and that engineering would be costly. Recording grey level is a very nonlinear function of laser beam current. Modulating the CRT for grey levels is less difficult but still would require costly redesign. No present manufacturer has plans to add grey level recording for commercial applications.

About the time we learned this information, we completed the system throughput analysis which showed that the system could not satisfy the volume requirement with multigrey level coding. See "System Throughput" in section 3.0. At this point we dropped multigrey level recording as a suitability constraint and concentrated on image enhancement (in the scanner) to satisfy legibility requirements.

3.8.1 Functional Requirements

The requirements we established for the recorder are:

a) Accept block mode transfers of compressed image data from the remote site minicomputer buffer memory.

b) Decompress the image data.

c) Produce bit (pixel) mapped recording on the whole fiche including the header area.

d) Provide 4800 lines/inch resolution.

e) Provide all film processing and output cut and dry microfiche facsimile.

f) The recorder shall provide throughput of at least one fiche every 60 seconds.

g) Dry process silver-based film is preferred because of development chemical handling considerations.

h) The recorder shall be suitable for use in a general office environment. Shall not produce excessive noise or heat.

i) Perform self testing and report own status to the remote site minicomputer.

3.8.2 Candidate Recorders

Three types of recorders were investigated:

1) Electron Beam Recorders

2) Amber CRT COM Recorders

3) Laser Beam COM Recorders

Electron Beam Recorders

The leader in EBR's is Image Graphics of Fairfield, CT. Their standard EBR is the only true bit mapped image recorder as opposed to COM Recorders. In other words, their EBR accepts bit mapped image data rather than computer output byte wide character data. The resolution ($\sim$ 5 micron) meets the requirements. However, they are relatively the most expensive ($\sim$ $300K), require a "computer room" environment and record on roll film in an evacuated film chamber. This latter characteristic requires the additional work to develop and cut the film in another machine. The EBR is a low volume product, less than 10 units per year.

Because of these negative characteristics, the EBR is judged to be not suitable for MITS II.

Amber CRT Recorders

These dry silver, cut fiche recorders are commercially available from a number of suppliers. Datagraphix provides the Auto COM II, 3M provides the Series 700 units and NCR provides similar recorders. The On-line Auto COM II is GSA listed at $96K and the 3M and NCR units are in the same price range, $80-$100K.

These recorders are mature products (Datagraphix reports 3800 installations; estimate about the same for 3M). But they are COM recorders which use old technology. For example, 3M uses DEC PDP-8 process controllers.

Resolution or spot size and speed are marginally adaquate for MITS II. Adapting these or similar units for MITS II (bit mapped) would be costly and time consuming. No manufacturer has indicated enthusiasm for adapting their present CRT recorders for bit mapped capability.

Laser Beam Recorder

Only two companies supply in volume Laser Beam COM recorders. Kodak makes the KOMStar LBR and Datagraphix makes the ARIS II. The more recent technology product is the ARIS II COM Recorder. First installations were made in approximately 1981 and at this time there are about 35 installations. GSA price is about $102K. It outputs dry process, cut microfiche. The KOMStar uses older technology which we judge not suitable for adapting to the MITS II requirements.

Discussions with Datagraphix engineers reveals an enthusiasm for adapting the ARIS II for the MITS II requirement. This is especially true when we discussed the whole fiche recording

concept. Resolution and speed are adequate. See Reference 30.

At this time, it is our opinion that the ARIS II is the leading candidate for the MITS II Recorder.

3.8.3 Characteristics of Leading Candidate

As stated above the ARIS II is a COM Recorder. It consists of two units, the Recorder (49.5" H X 44.5" W X 28" D) and the Controller (42" H X 36" W X 28" D). See Figure 3-19. Of particular interest for the MITS application are some of its characteristics, as discussed below:

<u>Image System</u>

Reference 31 states: "The image generator is a proprietary high energy raster scan system capable of exposing very high resolution heat developing silver halide films. High dot resolution provides easily readable and unambiguous printing of popular page formats and character sizes ..."

Note that the above quotation addresses standard COM recording. In other discussions with Datagraphix, including reference 32, we have learned that bit slice microprocessors are used in the recorder because of speed considerations. They would probably use the same type for a bit mapped recorder adaptation for MITS.

The laser beam can be deflected across a line about 14mm long. A bit mapped image can be printed from top to bottom in approximately 200 milliseconds with the required resolution. The sequence for printing images on the fiche is down the columns of

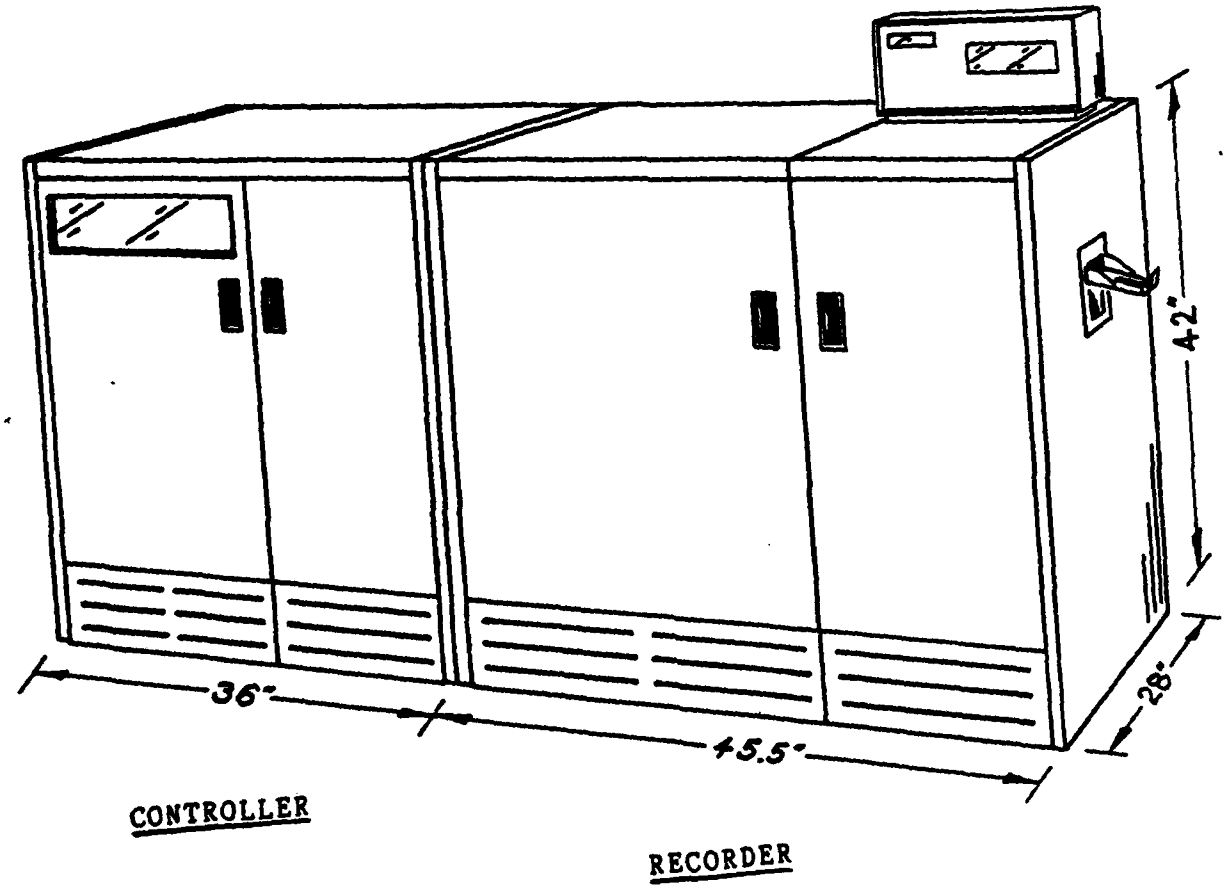


FIGURE 3-19 MICROFICHE RECORDER

images starting at the top of the first column. Flyback time to the top of the next column is approximately 250 ms. Thus, it requires about 23 seconds to print the fiche with 98 images, [(2x98)+(14x.25)=23.1]. With these estimates, and an estimate for printing the header area, the total time required to print a whole fiche is between 25 to 30 seconds.

Film Transport and Film Developing

Reference 31 states: "The unique, high speed film transport and shutterless camera increase the flexibility of Aris II through vertical page sequencing ... Data pages are imaged on a 105mm by 148mm cut, dry silver film with virtually no film waste". And, "The self-contained heat developer delivers dry, completely developed black-line microfiche suitable for immediate viewing or vesicular duplication. Development time per fiche is approximately 10 seconds."

The ARIS II uses the Datagraphix Type 64D1 recording film. The film is supplied in a preloaded cannister. The cannister holds 100 meters of film (approximately 675 fiche/cannister).

The spectral sensitivity of the film is matched to the helium-neon laser source (633 nm). Its resolution is 1000 lines/mm with test-object contrast of 1000:1. Its granularity is 11(Selwyn). Resolution and granularity are determined by ANSI PH2.33-1969 procedures.

The film is processed in total darkness by heating it to 239°F(±3°F) for approximately 5 seconds. The unopened film packages have a shelf life of about 6 months when properly stored

(70°max, 50% relative humidity, no x-ray or other radiation). Unexposed film within the prepackaged cannister can be handled in normal room light. All heat developing films continue to develop (darken) after exposure and normal processing. Therefore the fiche will not be archival quality. MITS II does not require archival quality. See Appendix A for the Type 64D1 Data Sheet.

Self Test, Status Monitoring and Reporting

The Aris II has other built-in features which could be easily adapted or modified for the self test and monitoring requirements. Under "Local and Remote Diagnostics" reference 31 states: "... Aris II is capable of local loading of diagnostic routines which enable system maintenance without channel disruption." And under "Operate Message Display" it later states: "Aris II constantly monitors operational equipment status and communicates to the operator through a series of messages displayed in English or the appropriate local language. The messages call attention to conditions requiring operator intervention (i.e. form slide required, film out, etc.)."

For MITS, these capabilities can easily be adapted to come under the control of and be communicated via the remote site minicomputer.

3.9 Ergonomics

The MITS I demonstration system required a high degree of operator effort. This manual effort was required for both the transaction process (record requesting, verification, and pulling records from MPRS) as well as the main process (scanning, data transmission, reception and facsimile recording).

The transaction process was totally manual; verbal request was made via telephone, and manual entry into MPRS terminal. That process required manual input (keystroking) of record header data, and a full time operator at the scanner to load each fiche.

The MITS I system or a similar MITS II implementation could not possibly handle the traffic volume, reliably, without a large number of trained operators.

This section discusses our concept of using separate microcomputer systems to relieve this human burden, increase reliability, and increase productivity.

3.9.1 Assessment of User and Operator Variables

Although the Navy Personnel Research and Development Center report documents general user satisfaction with the MITS I System, the sample is both small (seven operators) and biased (four of the respondents were contractor employees). In evaluating some of the major defects of the system, the two major weaknesses were found to be: a) system reliability and b) speed and efficiency of operation. See Reference 33.

We have attempted to remedy the former defect through our design of the main process subsystem . The second major defect

required an examination of human variables as well as system hardware and software.

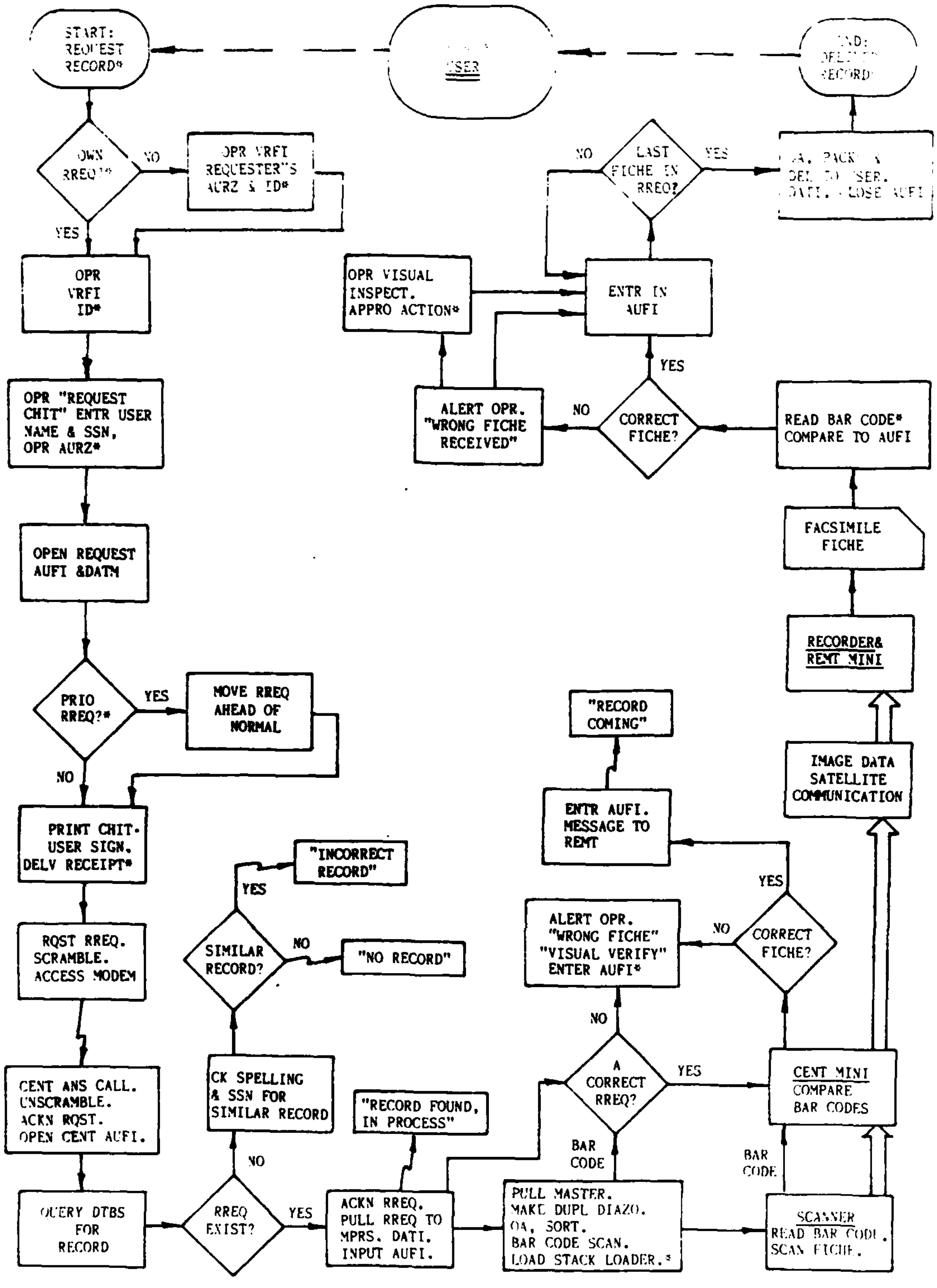
Our design calls for the use of linked microcomputers for transmission of personnel record requests. See Figure 3-20. This scheme allows for direct terminal entry of requests in response to a query program which eliminates the need for hand written request chits. The request is recorded on a floppy disk utilizing calendar/ clock entry and coded priorities. A printer produces the multipart request chit since signature record is required. The requests are batch transmitted to the Navy Personnel Records Center, ordered on the basis of entry time and priority, and cross checked automatically for the status of the record. This design also provides NMPC personnel with CRT and hard copy record orders, eliminating the need for a duplication of chit information through telephone orders and the associated probability of error. This design also eliminates the major part of the current record verification process and, at the same time, provides constant display of the operation of the main MITS process. The verified "pull record request" is entered automatically into the MPRS computer. Central Site personnel thus need only monitor the record request process.

It might be possible that the subsystem could be programmed to provide an estimate of main subsystem delivery time, based on existing backlog.

In summary, this design provides for:

a) Direct terminal data entry at the remote site.

b) Automated request chit



AURZ-Authorization
ID-Identification
VRFI-Verify
SSN-Social Security Number
ENTR-Enter
RCD-Record
MPRS-Military Personnel Record System
REMT-Remote [illegible]
DATM-Date & Time

CENT-Central Site
DTBS-Data Base Transaction
AUFI-Audit File(s)
PRIO-Priority
ACKN-Acknowledge
RREQ-Record Request
OPR-Operator
RQST-Request

* [illegible]
[illegible]

FIGURE 3-20 TRANSACTION PROCESS FLOW CHART

c) Ordering of requests based on submittal time and priority.

d) An on-line verification of existence of requested record.

e) Current information on main subsystem status.

f) The possibility of on-line turn-around time estimates for the requesting party.

3.9.2 Subsystem Requirements

The remote site system would be a dual floppy disk microcomputer with CRT monitor, printer, and remote communication capabilities. This could be a 64K RAM unit, but 128K of RAM would be preferable. The operator would directly input the requested personnel data in response to a query program.

Such a program would request the following information:

a) Date and Time of Request (Automatic)

b) Request Priority

c) Name and SSN of Requester

d) Operator Authorization

e) Request for Record Verification

f) Request for System Information

g) Request for estimated turn-around time in system minutes.

The remote microcomputer would be linked to the central site microcomputer with self dialing, self answering modem, either at the time of entry, or at such time as a line is available, the

request would be transmitted to the central site where it would be received through a similar modem.

The central site microcomputer would be similar to the remote system with the addition of a hard disk with approximately 15M bytes of memory storage. The disk would have the name and SSN of the estimated 800,000 individuals whose records are maintained at the center. This feature allows the cross checking of names and SSN's while the two microcomputers are interacting without inquiry to MPRS. Basic errors detected and the validation of existing records, would be transmitted back to the remote site at this point. This would be a "message received", "no record" or "message validated" response.

The central site microcomputer would also be able to transmit a direct response of "system up" or "system down" to the requesting source as a part of message acknowledgment. If there is no request traffic for a period of time, say 10 minutes, the system status would be automatically transmitted to the remote site.

The central site microcomputer unit would be receiving many continuous inputs from a number of remote units and one function of the central unit would be to rearrange requests as they are received in terms of requesting unit real time and priority.

It is possibly, with a slightly more sophisticated subroutine that there could be an immediate feedback from the central unit to the requesting unit of the current record request backlog and an estimate of turn-around time in system minutes.

The central unit could have both hard copy and CRT orderings based on each new transmittal of confirmed requests. The manual retrieval and loading of microfiche into the scanner is covered elsewhere.

3.9.3 Microcomputer Hardware/Software and Costs

The leading candidate microcomputer is the state-of-the-art IBM-PC. At this point, this unit has the widest available range of peripherals and off-the-shelf applications software. Some cost savings could be achieved by the use of the "look alike" units which are coming on the market, many with claimed capabilities superior to the IBM-PC. These include units like the Toshiba T300, the Hewlett Packard 150, or the TI Personal.

Some simple modular additions would be required to have multiple serial interfaces (RS232 I/O): one for the modem, one from the MITS minicomputer, and one for the MPRS I/O.

The microcomputer would be supported by a dot matrix printer and CRT at each site. Each site would require a self-dialing, self-answering modem.

The central site microcomputer would include the supplemental hard disk data base containing names and SSNs of Navy personnel.

Almost any data base management program, such as dBase II or a similar equivalent, would be needed with the system. For request entry, there are a number of commercial "Order Entry" application programs on the market but they tend to be limited and lack the necessary modification capability. A standard General Ledger accounting package might be adaptable for transaction

auditing. If the latter proved feasible, dollar amounts for revenue, costs, etc. would be replaced by another measure of "value" - for example, system resource time (seconds).

Subsystem cost is estimated as follows:

CENTRAL MICROCOMPUTER		REMOTE MICROCOMPUTER	
Dual Disk CPU	$3,000	Dual Disk CPU	$3,000
CRT	300	CRT	300
Dot Matrix Printer	700	Dot Matrix Printer	700
Cables & Extra Parts	300	Cables and Extra Parts	300
300/1200 Baud modem	600	300/1200 Baud modem	600
15M Winchester Disk	1,500		
Totals	$6,400		$4,900

SOFTWARE

Data Base Mgr.	$600
Application Software	2,000

SYSTEM TOTAL (One Requesting Unit)

$13,900

3.9.4 System Benefits

The major advantages of the system are as follows:

a) Ease of input

b) Rapid validation of request

c) Elimination of copying error

d) Automatic ordering of requests

e) Automatic monitoring of main MITS unit

f) Continued functioning of input even if main MITS process is down; requests continue to be accepted

g) Estimated turn-around time returned immediately to requester.

An additional advantage of this design is the availability of a microcomputer for other uses at the remote site. While it is recommended that the unit at the Navy Personnel Records Center be a dedicated unit (and, therefore, available on a 24 hour basis), the requester units are available for other functions, such as word processing and local records maintenance.

4.0 RELIABILITY, MAINTAINABILITY AND AVAILABILITY

This section summarizes our recommendations in response to statement of work item 9 "Improved System reliability and maintainability." We have analyzed the MITS I design, its performance, and the MITS II requirements and have established an overall system availability goal (recommendation) of 0.909. This means that the ratio of MTBF to MTTR is 10:1. In order to achieve this system level of availability, individual elements of the system must have MTBF/MTTR of greater than 10, and R&M budgets must be assigned. In some critical areas involving new design, we have suggested what we believe are realistic and necessary goals. See section 3.4.4.

Our system level design includes a number of characteristics which we believe will make it possible to achieve or exceed an availability 0.909. These characteristics include:

a) The use of dual redundant hard disks at each site to store the image data.

b) The selection of minicomputers that are mature products with good, reliable usage history (over 300,000 system installations).

c) A scanner design with simple stack loader and fiche transport mechanism. This mechanical design (made possible by the use of the fiber optic bundle) permits the minimum number of moving parts.

d) The use of dry process film in the facsimile recorder eliminates the problem of handling film development chemicals. The large capacity film cassette is quick and

easy to load, and only one or two daily reloads will be necessary. The system "down-time" for film loading should be no more than 5 minutes per day when the recorder is operating at maximum capacity.

e) The use of separate microcomputer based transaction processors permits functional features tending toward high overall system availability. These include: 1) Permitting the continuation of request order taking during the down-time of main process hardware, 2) Without the burden of transaction processing, the minicomputer main process controllers can be used for extensive system self test, fault detection, and fault localization. This characteristic will greatly shorten repair time, 3) Degraded performance rather than total system failure in the event that the microcomputers fail. In that case record requests can still be processed manually, ie. verbal request via scrambled telephone lines and manual pull record request input at the central site MPRS terminal.

The detailed R&M engineering work for MITS II will be the responsibility of the SIC. Only the SIC would possess (or could collect) the data required. Our basic point, however, is that this QA engineering is just as important as the detailed design engineering and the QA engineering must be integrated with the design engineering.

The following sections offer our general recommendations.

4.1 Component and Equipment Selection Criteria

We recommend that sole source components (ie. ICs, and other discretes) be minimized. This factor relates mainly to the electronics. Where second sources are not available (i.e., EO Sensors), the design should include provisions for using "almost equivalent" components such as those with different "pin-outs".

Second sourcing for equipment (ie. comm interface units, scanner) is not possible. However, some industry, IEEE and de facto standards do exist. This is especially true with microprocessors. Since much of the equipment is "smart" (i.e., microprocessor based), the SIC should select only broadly supported bus standards such as the Q bus, Multibus, STD bus, etc.

4.2 Spare Parts Recommendations

We recommend that the SIC provide spare parts sufficient to achieve the system availability level of 0.909 over a six month trial period. Spares should be module rather than components wherever practical. For those system elements that are essentially adapted commercial products; i.e. minicomputers, microcomputers, recorder, etc; the recommendation of the OEM should be followed. Modules (ie. PC cards, power supplies, subassemblies) used in field repair should be recycled (repaired by original supplier and returned to spare parts inventory). In this way historical reliability data would be achieved.

Parts which would exhibit very low failure rates <u>and</u> which are relatively expensive, i.e. fiber optic bundle, need not be spared.

4.3 Maintenance Service Recommendations

We recommend that the SIC provide complete maintenance service for an initial six (6) month evaluation period. During this time the SIC should prepare documents of failure reports, repair action reports, routine maintenance reports, and other documentation (either manually or using the transaction process microcomputers) for analysis after the trial period.

We also recommend that the SIC provide training to the Navy's current support contractors at each site, during the evaluation period. For example, the current support contractor at NMPC should be trained. NOSC also currently has maintenance support contractors for Center wide minicomputers, software support, communications equipment, etc. These contractor people should be trained so that they could immediately take over maintenance of MITS after the evaluation period.

This training should be given in accordance with the Government approved training plan prepared by the SIC. Training should cover both operator and maintenance personnel. Self training computer programs might be used for part of the maintenance training. In this case, the micros or minis at each site could be used.

We also recommend that the training course lessons be video taped on-site. These audio-visual aids can be used later for refresher courses or to train new operators and maintenance personnel.

5.0 SUMMARY PERFORMANCE SPECIFICATION

This section summarizes the system level performance of our design. This brief specification should not be confused with any Government Specification, nor does it have any standing in the order of precedence of any Government contract, current or future.

The MITS II initial installation shall be capable of electronically transmitting microfiche personnel records from the Navy Military Personnel Command (NMPC) in Washington D.C. to a Naval activity located in San Diego, California. After evaluation of this initial installation, other remote sites may be added.

MITS II shall consist of two functional subsystems:

1) Microcomputer-based transaction process subsystem, and the

2) Microfiche scanning, data transmission and facsimile process subsystem.

5.1 Transaction Process Subsystem

The transaction subsystem shall provide:

Request Volume	300 records/day, min.
Automatic Request Chit	3-part computer generated form, automatic date and time.
Authorization Verification	On-line Verification of Remote Site Operator's Authorization.
Record Verification	On-line verification of the existance of the record at NMPC.
Pull Record Request	Automatic, validated, prioritized input to MPRS in response to remote site requests.
Request Acknowledgement	Automatic feedback to remote site that record request is in process.
Transaction Auditing	a) Accept bar code scan of duplicate fiche during hand sorting. Time of action. b) Accept bar code scan from microfiche scanner. Time of action. c) Accept bar code scan or manual ID of received facsimile fiche. Time of action.

d) Produce daily or on demand hardcopy reports of all MITS transactions at both sites.

e) Maintain running display of transactions in process at Central Site.

System Status Monitoring	a) Accept status messages from two main process mini-computers. Tag time of message.
	b) Transmit central site status to remote site via transaction process communications channel.
	c) Display system status at both sites.
	d) Provide audible and visual alarms for fault conditions.
	e) Provide audible and visual alarms for conditions requiring operator intervention (i.e. Stack-Loader Low, Film Out, etc.) at both sites.
	f) Record status conditions with time and date tags.

g) Produce daily or on demand hardcopy system status reports.

5.2 Scanning, Data and Facsimile Process Subsystem

5.2.1 General

Input	NMA Type I, 24X, 98 image microfiche. Negative image polarity. Diazo duplicates of silver halide masters. 4.13" X 5.83" X .007"
Format	See Figures 5-1, 5-2 and 5-3.
Central Site Location	NMPC, Washington DC.
1st Remote Site Location	Naval Activity (TBD), San Diego, CA.
Volume	300 records/day, min. (1000 fiche/day, 50,000 images/day)
Turnaround	Regular request, 24 hours, max. Priority request, 30 minutes, max.
Output	Facsimile 24X, 98 image microfiche.
Operating Personnel	Civilian clerical at NMPC, Navy military or civilian clerical at San Diego.
Operating Environment	Normal general office.
Operating Hours	0400 to 0000 Pacific Time (20 hours). Monday through Friday.
Maintenance Hours	0000 to 0400 Pacific Time (4 hours).

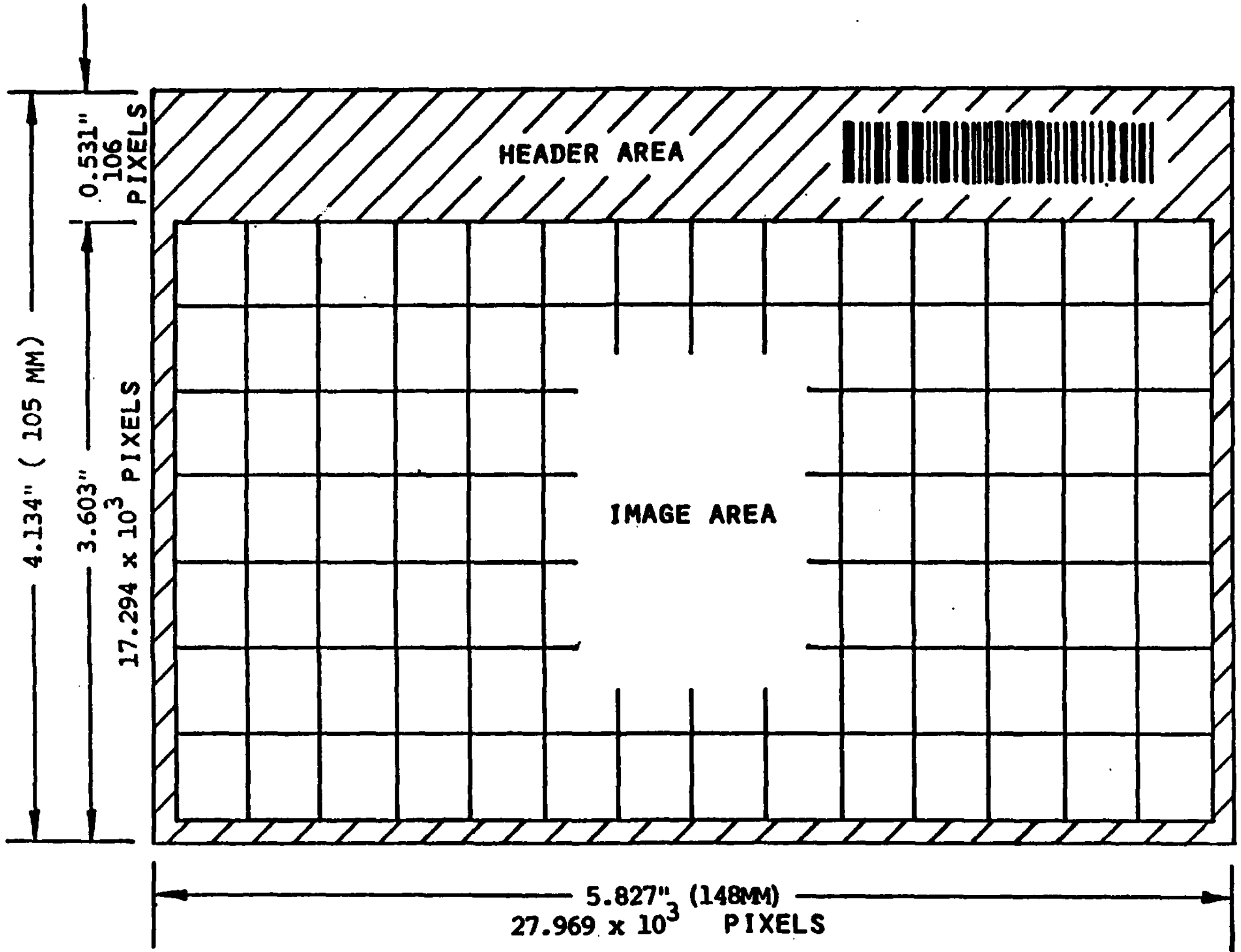


FIGURE 5-1 MICROFICHE FORMAT

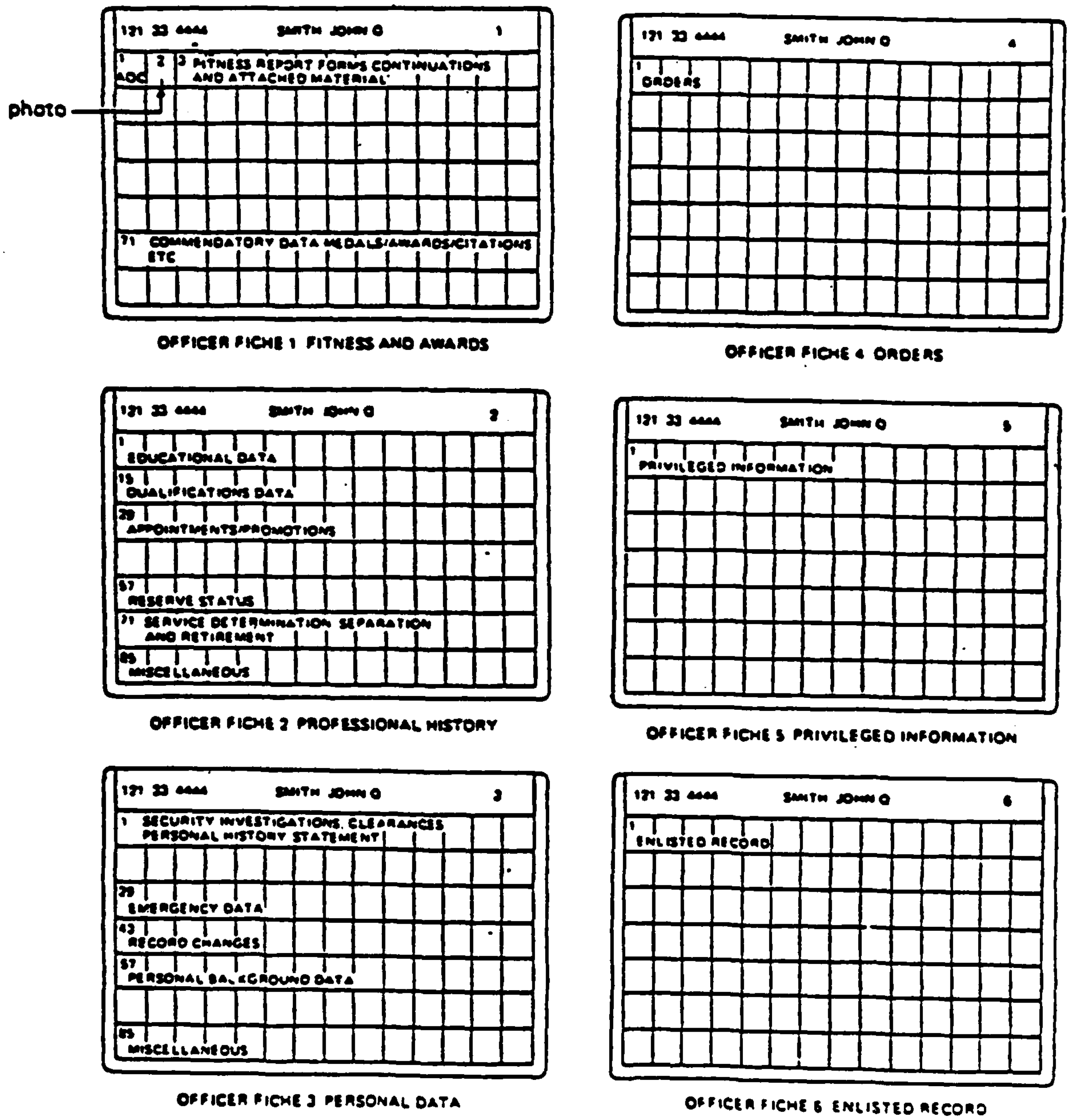
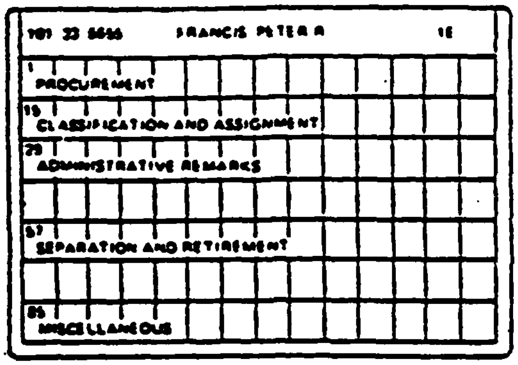
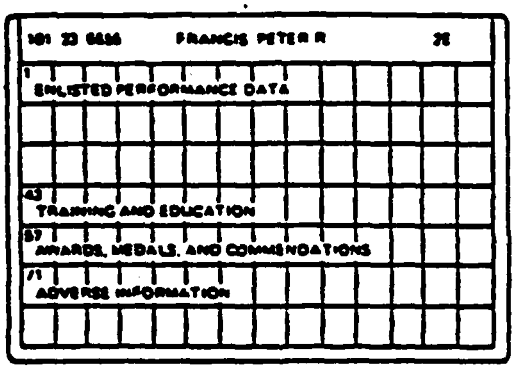


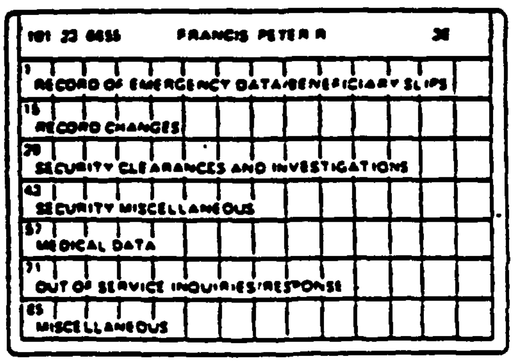
FIGURE 5-2 RECORD FORMATS FOR OFFICERS



ENLISTED FICHE 1E PROFESSIONAL SERVICE HISTORY



ENLISTED FICHE 2E
PERFORMANCE EVALUATION AND TRAINING DATA



ENLISTED FICHE 3E PERSONAL DATA

FIGURE 5-3 RECORD FORMATS FOR ENLISTED PERSONNEL

5.2.2 Scanner

Stack Loader	Capacity, 100 fiche, min. Throughput, 1000 fiche/day, min.
Bar Code Reader	Automatic reading of the modified code 39 bar code and data (bar code) transmission to minicomputer. See Appendix A for format.
Resolution	4800 lines/inch, image area. 200 lines/inch, header area. Both required.
Throughput Rate	1 fiche every 60 seconds, min.
Image Enhancement	Text material enhancement such that remote site facsimile is at least as legible as the diazo duplicate input. Output to be bitonal (1 bit/pixel). Data quantity of output is to be no more than 4.464×10^6 bits/image.
Compressor	2-D run length coding. Compression ratio 5:1, min, for real images. CR 50:1, min, for blank images.

Output	Output buffer and 16 bit parallel interface for Block Mode DMA transfers. Rate 625 KWPS, min.

5.2.3 Central Site Process Controller

The process controller shall be a commercially available mini- computer with conventional bus architecture.

Data Interfaces	a) 2 dedicated DMA I/O interfaces for Image Data. b) Quad Serial (RS-232) interfaces. c) Quad Parallel (64 line) interface for test and control.
Memory	512KB, RAM, min.
Mass Storage	a) 2 each, 20 MByte, hard disks and controllers for image data storage. b) Dual Floppy Disk, 1 MByte min, with controller for maintenance, software loading and development.
CPU	Suitable CPU for the required process control, image data buffering, system monitoring and test, and communications.

Programmable Real Time Clock	Suitable realtime clock for process control.
Terminal	A video terminal shall be provided for use as the system terminal for hardware/software test, maintenance and repair.
Operating System	Efficient, single user operating system with foreground/background modes.
High Level Programming Language	An efficient, mature version of PASCAL which is supported by the operating system.
Application Programs	PASCAL coded programs to perform: 1) Process Control, 2) Image Data Buffering, 3) Communications, 4) Self Test, and 5) System Monitor & Test.

5.2.4 Satellite Interfaces

These units shall interface between the minicomputers and the satellite link modems at both sites.

Link Image Data Rate	1.544 MBPS (T1 STD)
Protocol Efficiency	90%, min.
Control/Test Channel Rate	9600 Baud modems each end.
Image Data Input	16 Bit Parallel Block Mode DMA, 625 KWPS min, compatible to minicomputer.

Image Data Buffer Requirement	64K Word, min.
Link Availability	0.99, min.

5.2.5 Remote Site Process Controller

Remote site process controller shall be a hardware duplicate of the Central Site equipment (see 5.2.3). Application software shall be tailored to the needs of the remote site process.

5.2.6 Facsimile Fiche Recorder

The recorder shall be a modification and adaptation of a suitable, commercially available laser beam COM Recorder. It shall include suitable, real time data decompression electronics.

Image Data Input	16 Bit Parallel Block Mode DMA of compressed data from minicomputer.
Output	4800 line/inch resolution, legible, 24X, cut and dry microfiche facsimile.
Throughput Rate	1 fiche every 60 seconds, min.
Self Test and Reporting	Real time self test and monitoring. Reporting to minicomputer via a separate 16 Bit parallel channel.

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32. TELECON, L. Toth/ASC with A.S. Carnhan/Datagraphix, 28 November, 1983.

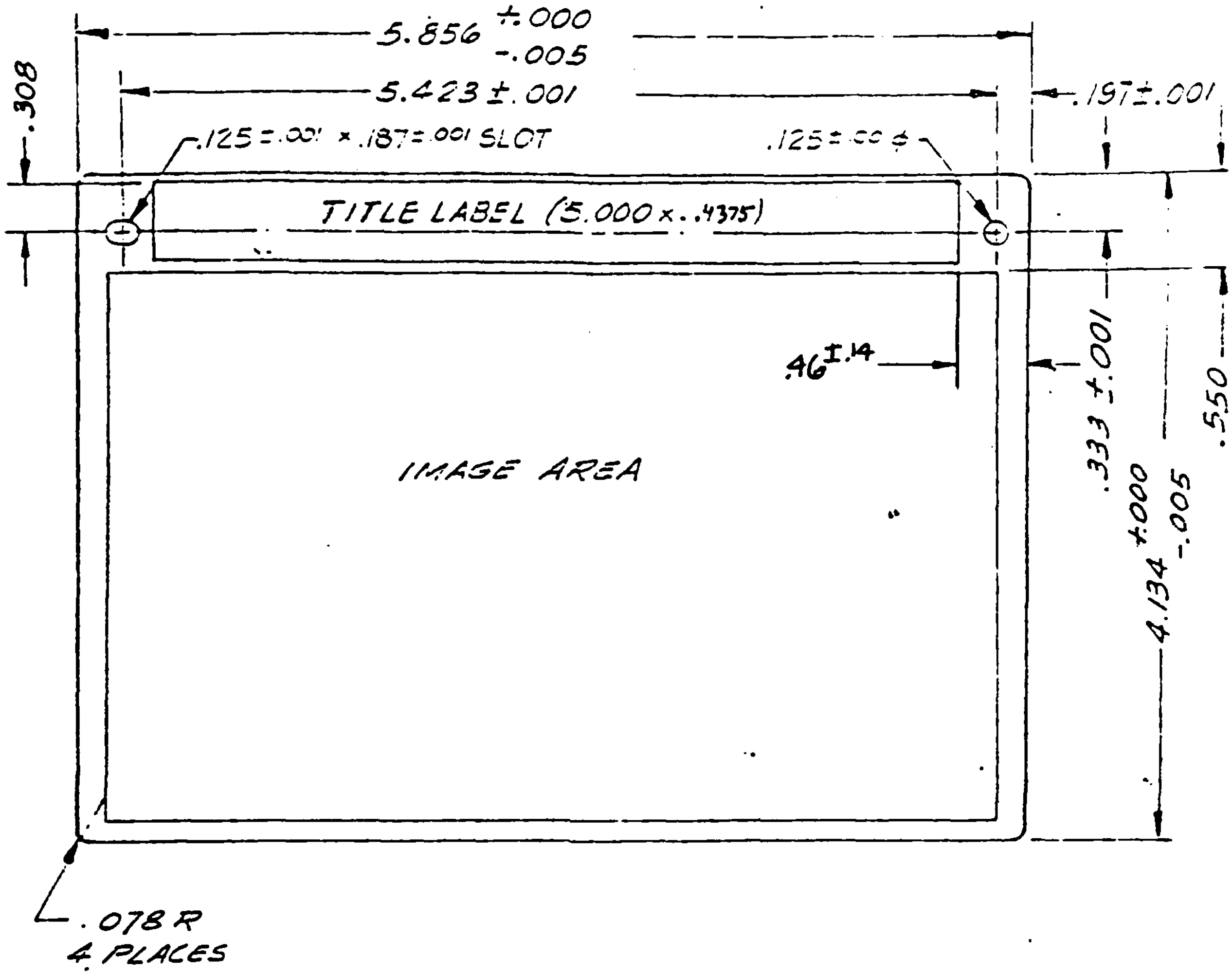
Section 3.9.1

33. John P. Sheposh and Vel N. Hulton, "Implementation of Microfiche Image Transmission System (MITS): A Multifaceted Assessment of Demonstration Installation", NPRDC Report SR 83-40, June 1983.

APPENDIX A

MISCELLANEOUS TECHNICAL DATA

BAR CODE ON FICHE A1-1

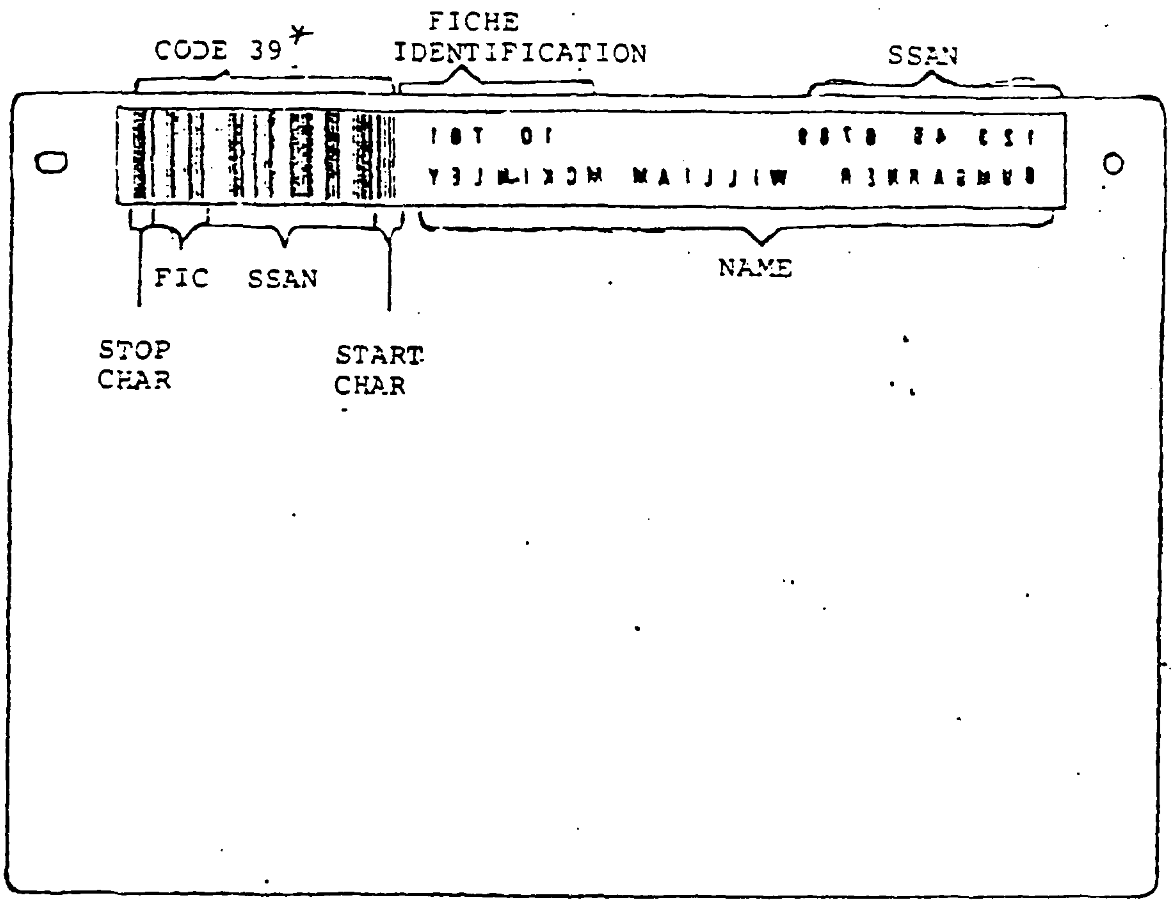


Notes:

1. Drawing not to scale.
2. All dimensions are in inches.

MICROFICHE TITLE LABEL PLACEMENT

Figure 2

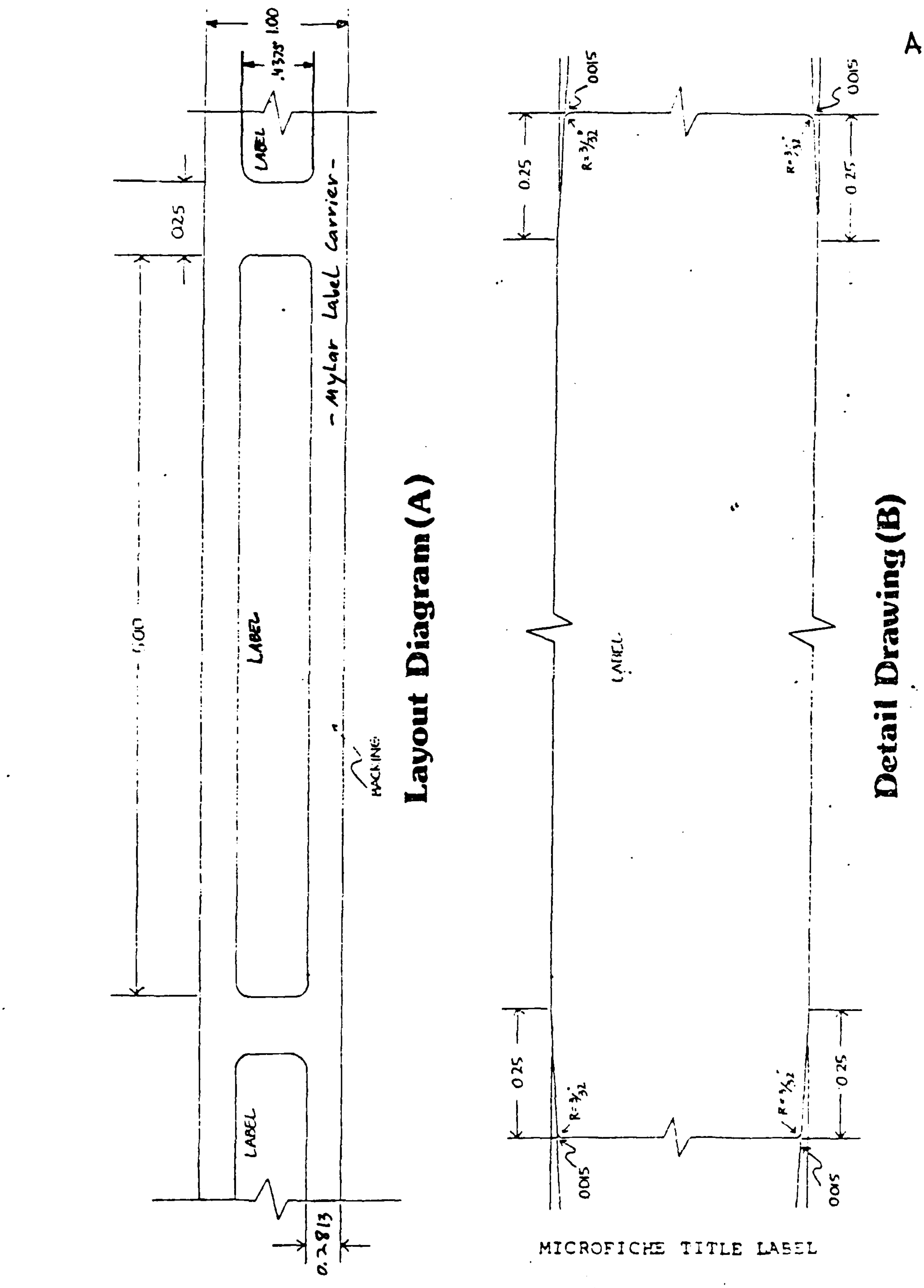


MICROFICHE LABEL FORMAT
(PRINTED IN MIRROR IMAGE AS SHOWN)
Figure 2a

* BARCODE CONSISTS OF 14 NUMERIC CHARACTERS:

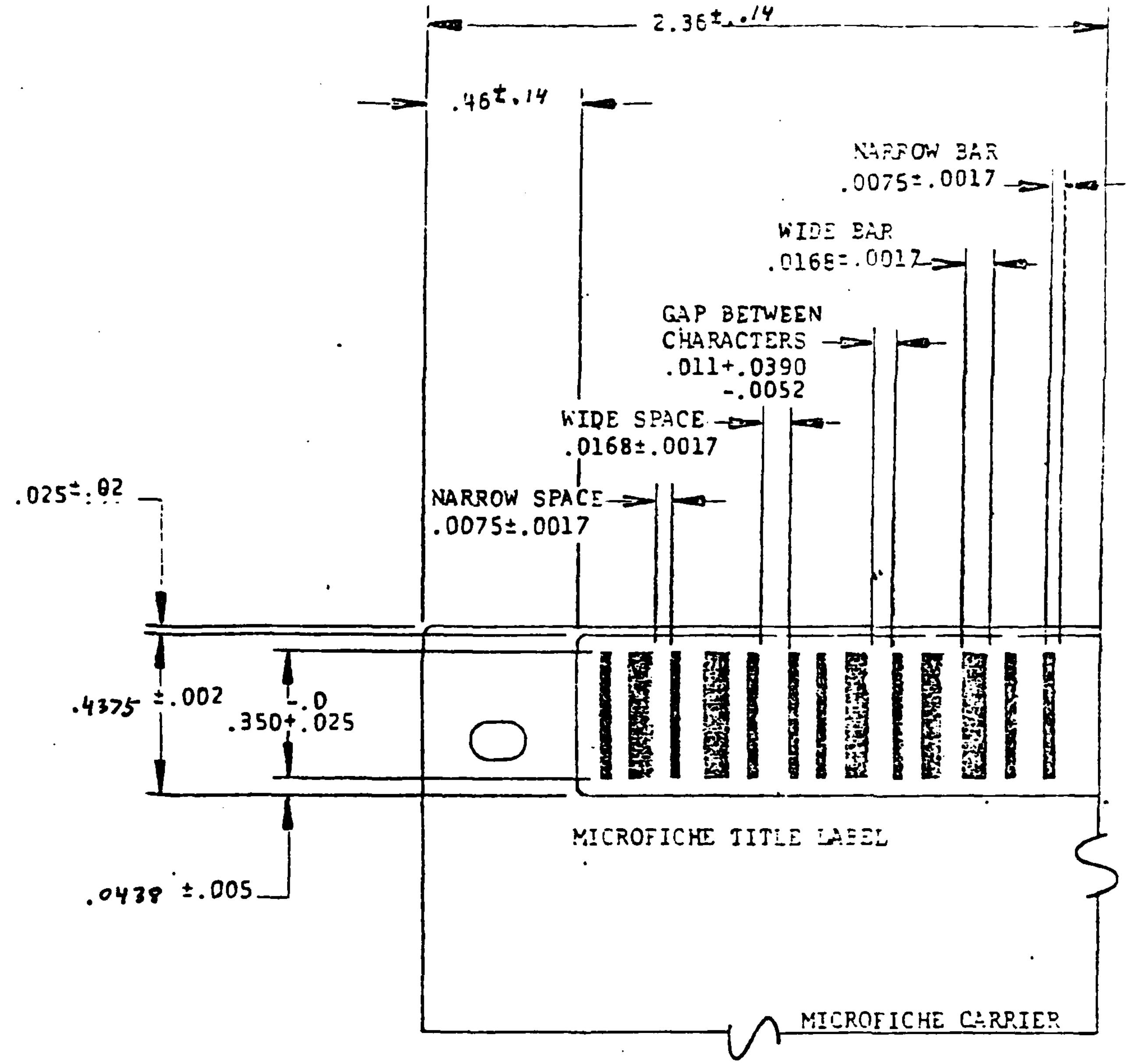
- START (1 CHAR)
- SOCIAL SECURITY NUMBER (9 CHAR)
- FICHE ID CODE (3 CHAR):

100 = OFFICER FICHE 1; 101 = 1TO1, [illegible]
⋮
600 = OFFICER FICHE 6; 601 = 6TO1
700 = ENLISTED FICHE 1E; 701 = 1ETO1
⋮
900 = ENLISTED FICHE 3E; 901 = 3ETO1.



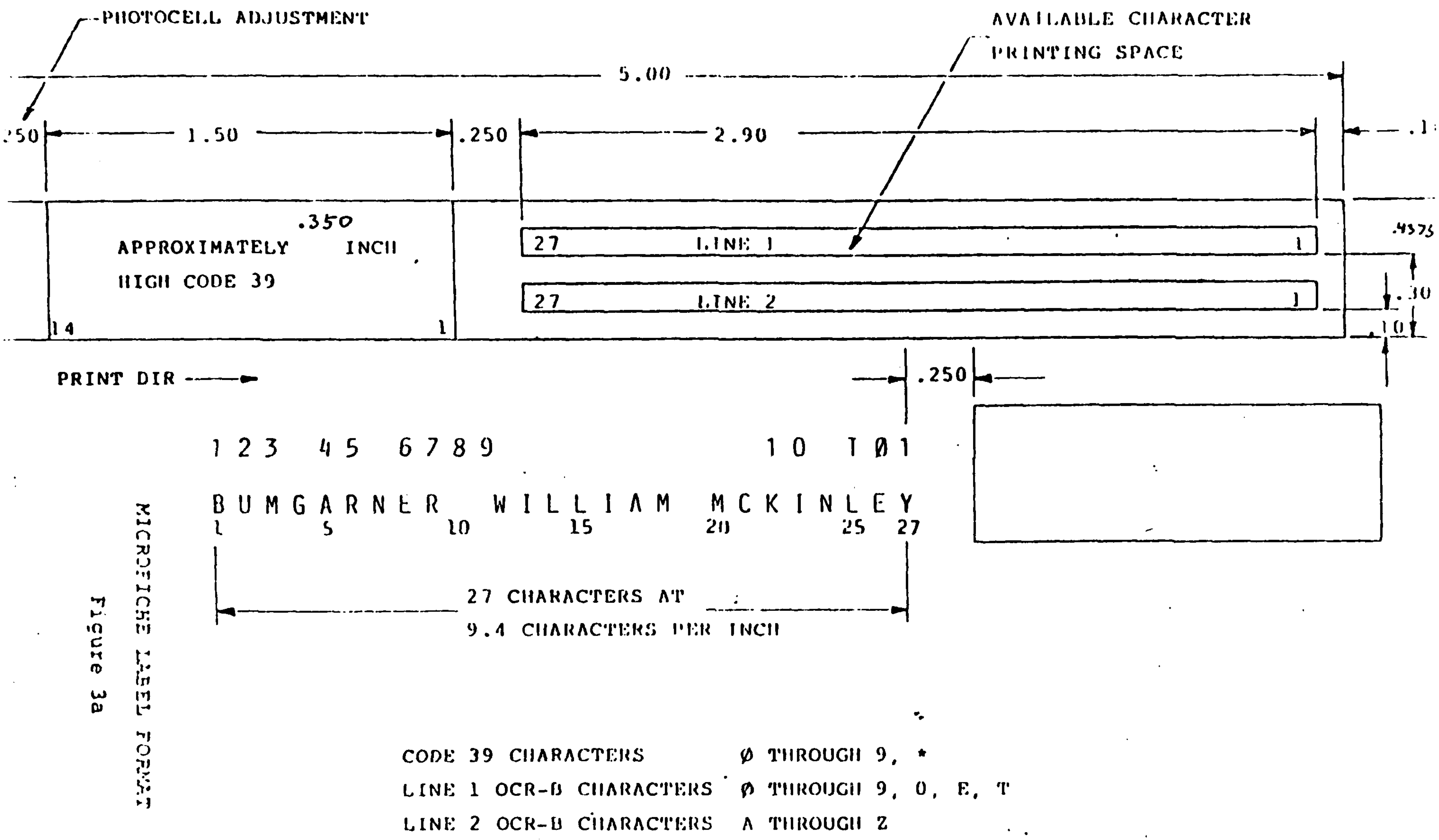
MICROFICHE TITLE LABEL

Figure 2b



NOTES:
1. CODE 39, BASE 43 CHARACTER CODE DENSITY SHALL BE 9.4 CHARACTERS PER INCH
2. ILLUSTRATION NOT TO SCALE
3. ALL DIMENSIONS ARE IN INCHES

TITLE LABEL CODE ILLUSTRATION



MICROFICHE LABEL FORMAT

Figure 3a

BAR CODE READERS

The addition of the bar code label on the record fiche permits elimination of <u>all</u> keystroking at the central site. See page 47 of MITS Demo Report, NOSC TR 813.

Our system level implementation calls for the following use of the bar code within the MITS II:

1) Scanning the bar code on the duplicate diazo with a handheld wand connected to the central site microcomputer.

2) Micro flags the fiche as correct request input to scanner.

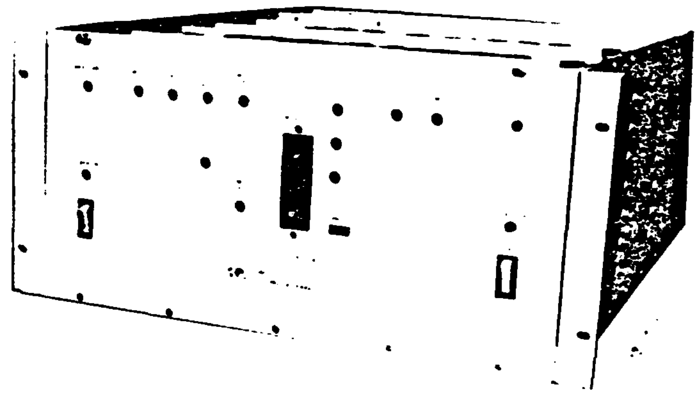
3) Reading the bar code again within the scanner and reporting via minicomputer to the transaction auditing microcomputer.

4) The use of a handheld wand at the remote site to acknowledge receipt of the fax fiche during QA, sorting and packaging. Possible only if recorder produces a duplicate of the whole fiche and if bar code background is not too opaque on diazo duplicate.

EXAMPLES OF BAR CODE READER

MFG/MODEL	APPLICATION
Scan-A-Matic Corp/Series S23	Bar Code Scanner in Fiche Scanner.
Digitronics/BCR 232	Handheld reader with RS-232 I/O
Caere Corp/240	Handheld wand with IBM PC input.
Computer Identics/FCP-10	Handheld wand for installation in DEC Terminals.

SM200A Satellite Modem
(–X101 Shelf)



SM200A Satellite Modem
with 1:1 Switch
(–X102 Shelf)

FEATURES

- **QPSK/BPSK Modulation**
- **16 Kbps to 6.0 Mbps**
- **Sequential or Threshold Decoding**
- **Optional 52 to 88 MHz Agility**
- **Data and IF Loopback**
- **Bandwidth Efficient**

APPLICATIONS

- **Satellite Communications**
- **Point-to-Point and Multidrop**
- **Single Channel per Carrier (SCPC)**
- **Process Automation, Robotics, Telemetry, Remote Data Processing**
- **Computer-to-Computer and PBX Traffic**

INTRODUCTION

The SM200A Satellite Modem has been designed for use with 70 MHz IF satellite communications equipment to allow the transmission and reception of digital data via satellite. It may be used in full-duplex or simplex data links operating at data rates ranging from 16 Kbps to 6.0 Mbps. An optional integral 1:1 switch also allows use in situations requiring automatic backup in the event of an on-line failure. Installations having more extensive backup requirements may use the companion SE-381 1:8 Modem Switch.

Error correcting convolutional encoding plus either soft-decision sequential decoding (up to 2.048 Mbps) or hard-decision threshold decoding are used to provide exceptional bit error rate performance. Actual modem performance using sequential decoding is guaranteed not to deviate from theoretical performance by more than 1.2dB.

One other outstanding feature of the SM200A is a high-slope modulator output spectral density. This characteristic defines the rectangularity of the output frequency spectrum and determines the minimum channel spacing. This in turn dictates the number of channels that may be used on a satellite transponder and also the transponder cost for each. The SM200A filter performance reduces this channel spacing to .7 times the symbol rate for versions using QPSK and 1.4 times the symbol rate for versions using BPSK. This can mean lower operating costs in many situations.

Several SM200A configurations are available to allow a modem to be tailored for a specific application. Full duplex or simplex operation, frequency agility, power supply redundancy, AC or DC power operation, and 1:1 switching capabilities may be supplied. Fault monitoring, V.35 scrambling-descrambling, and baseband/IF loopback functions are standard on all configurations.

GENERAL

The standard modem configuration is referred to as a −X101 shelf and is shown in the block diagram of Figure 1. The 1:1 switch configuration, referred to as a −X102 shelf, is used to provide redundancy for an on-line −X101 shelf and is shown in *Figure 2. Fault monitoring is not shown but is provided for all* modules.

−X101 SHELF

This shelf is the mainframe for the standard modem. The 8 3/4" high chassis is designed for mounting in a standard 19" rack. It will accept a CODER module, MODULATOR module, DEMODULATOR module, DECODER module, up to two optional SYNTHESIZER modules, and up to two POWER SUPPLY modules (the second is optional). Included is a 52 to 88 MHz bandpass filter for the modulator RF output and connectors for data, power, faults, modulator and demodulator external L.O. inputs, RF input, and RF output.

−X102 SHELF

This shelf is the mainframe for the modem incorporating the 1:1 switch. It is dimensionally similar to the −X101 shelf and accepts the same number and types of modules used in the −X101 shelf. An additional module, a 1:1 SWITCH, is used for data and modulator RF output switching. It also provides additional connectors for attachment to an on-line modem and a front panel bridge monitoring connector (not shown).

CODER MODULE

The CODER module accepts data and clock lines from the data interface connector and provides a convolutionally and differentially encoded output for use by the MODULATOR module. The data interface type may be either V.35, MIL-STD-188, RS-449, Bell T1 (DS-1), RS-232, or TTL. Other interface types may also be supplied. Coding rates may be selected as either 1/2, 3/4, or 7/8 when sequential decoding is used and 7/8 when threshold decoding is used. A V.35 scrambler may also be switched into the data stream if desired.

MODULATOR MODULE

The MODULATOR module uses the encoder output of the CODER module to produce a QPSK or BPSK modulated RF carrier within the range of 52 to 88 MHz. The carrier frequency is determined by either an on-board crystal controlled local oscillator (L.O.) or an external oscillator such as the optional SYNTHESIZER module. Nyquist filtering limits the modulated bandwidth to .7 times the symbol rate (QPSK) and a rear-panel bandpass filter removes out-of-band RF components.

Switch selectable L.O. routing is provided to ease IF loopback testing. This routing supplies the modulator L.O. signal to the demodulator so that it will operate on the same frequency as the modulator. An external cable is then used at the rear panel to supply the modulator output to the demodulator input.

DEMODULATOR MODULE

The DEMODULATOR module accepts a 52 to 88 MHz IF input and performs QPSK or BPSK demodulation at a carrier frequency determined by either an on-board crystal controlled L.O. or an external oscillator such as the optional SYNTHESIZER module. The encoded output is provided to the DECODER module where the data is recovered using either sequential or threshold decoding.

The use of dual RF conversion reduces image response and increased filtering in the second IF stage increases the available dynamic range. The performance results for a 56 Kbps data rate are shown in Figure 3.

Either soft decision or hard decision outputs are provided for use by the DECODER module. Soft decision is standard and is used for sequential decoding. Hard decision logic is provided when threshold decoding is required.

DECODER MODULE

The DECODER module accepts either soft or hard decision outputs from the DEMODULATOR module and provides data and clock outputs conforming to any of the interface types mentioned in the CODER module discussion. Sequential decoding is performed on soft decision inputs and threshold decoding is performed on hard decision inputs. Grey code differential decoding and V.35 compatible descrambling (switch enabled) are also provided.

The use of sequential decoding provides significant coding gain. Typical bit error rate performance is shown in Figure 4 for data rates of 56 Kbps and 1.544 Mbps using encoding rates of 1/2 and 7/8.

SYNTHESIZER MODULE

Up to two SYNTHESIZER modules may be used in either the −X101 or −X102 shelf. These provide detent tuning in 25 KHz steps using BCD rotary switches at the front of the modules. Full operation is provided over the 52 to 88 MHz IF range and a remote tuning capability may be provided.

1:1 SWITCH MODULE

The 1:1 SWITCH module is used only in the −X102 shelf. It provides relay switching of the data interfaces and RF output lines in hot-standby configurations (see Figure 2). The failure of a −X101 on-line modem activates the relays, switching either the −X102 modulator, demodulator, or both on-line depending on the failure.

POWER SUPPLY MODULES

Four types of POWER SUPPLY modules are available to allow operation from 115 VAC, 230 VAC, −48 VDC, or −24 VDC. One module will power a full −X101 or −X102 shelf and an optional second module may be used for redundancy. Each module provides a shelf fault summary Form C relay closure at the rear panel.

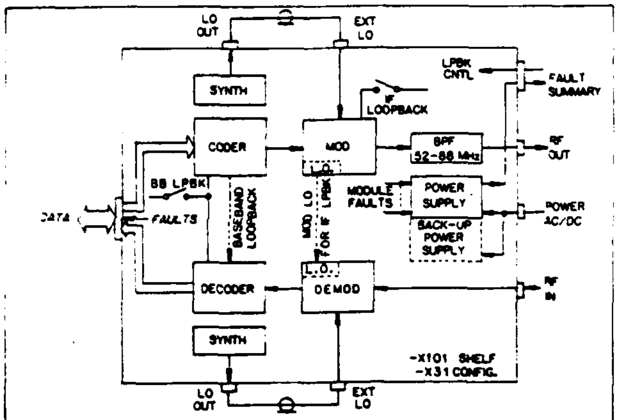


FIGURE 1. STANDARD MODEM BLOCK DIAGRAM.

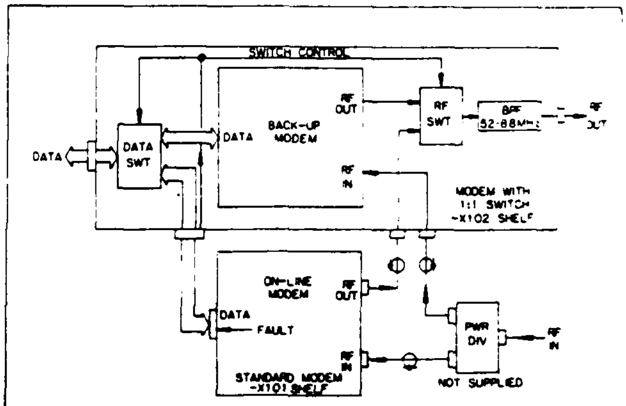


FIGURE 2. REDUNDANT MODEM CONFIGURATION USING STANDARD -X101 MODEM ON-LINE AND -X102 MODEM WITH 1:1 SWITCH FOR BACK-UP UNIT.

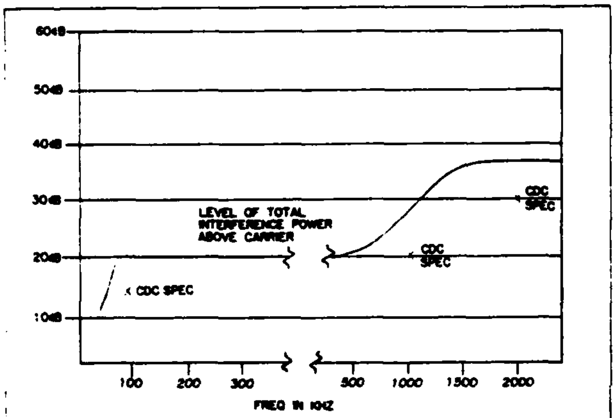


FIGURE 3. TYPICAL INTERFERENCE PERFORMANCE FOR .5dB DEGRADATION AT 56 KBPS.

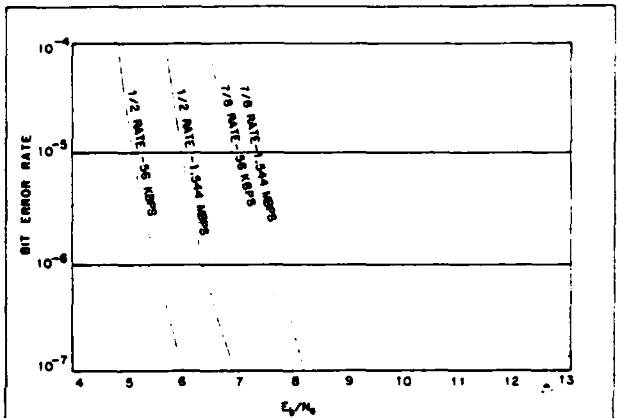


FIGURE 4. BER APPROXIMATION CURVES FOR 56 KBPS AND 1.544 MBPS OPERATION.

ORDERING INFORMATION

EXAMPLE **M200-X31-BB4ASEBN**

Power Supplies	Configuration	Freq. Control	Chassis # w/o 1:1 SWT	Chassis # with 1:1 SWT
1	Mod/coder/ Demod/Decoder	2 Synth.	-X31	-X43
		2 L.O.	-X32	-X44
	Mod/Coder Only	1 Synth.	-X33	-X45
		1 L.O.	-X34	-X46
	Demod/Decoder Only	1 Synth.	-X35	-X47
		1 L.O.	-X36	-X48
2	Mod/Coder/ Demod/Decoder	2 Synth.	-X37	-X49
		2 L.O.	-X38	-X50
	Mod/Coder Only	1 Synth.	-X39	-X51
		1 L.O.	-X40	-X52
	Demod/Decoder Only	1 Synth.	-X41	-X53
		1 L.O.	-X42	-X54

BIT RATE

AA = 19.2KB
BB = 50KB
CC = 56KB
DD = 192KB
EE = 208KB
FF = 224KB
HH = 550.5024KB
JJ = 772KB
KK = 1544KB
LL = 16KB
MM = 100KB
NN = 1344KB
PP = 193KB

BIT RATE

RR = 450.33KB
SS = 153.6KB
TT = 37.7KB
UU = 112KB
VV = 256KB
WW = 448KB
YY = 3072KB
ZZ = 1536KB
AB = 384KB
AC = 500KB
AD = 768KB
AE = 86.4KB
AF = 128KB

CODE RATE

2 = 1/2
4 = 3/4
8 = 7/8

INTERFACE

A = V.35
B = MIL-188C
C = MIL-188-114
D = EIA-449
E = T1
F = RS-232
H = TTL
J = RS-422
K = RS-423

CODE TYPE

T = Threshold
S = Sequential

LO

I = Internal
E = External

MODULATION

B = BPSK
Q = QPSK

MODEL

O = CDM-78
N = SM200A

GENERAL

Communication Modes	Full duplex, simplex.
Operating Modes	Normal, baseband loopback, IF loopback.
Modulation	QPSK standard, BPSK optional.
Coding	Grey code differential plus either sequential or threshold coding/decoding. V.35 scrambling and descrambling are switch selectable.
Data Interfaces	See Configuration Code below.
Data Rates	16 Kbps to 2.048 Mbps using sequential decoding. 16 Kbps to 6.0 Mbps using threshold decoding.
Coding Rates	1/2, 3/4, 7/8.
Carrier Spacing	QPSK: 0.7 [(Data Rate)/(Coding Rate)]. BPSK: 1.4 [(Data Rate)/(Coding Rate)].
Physical	19" wide by 8 3/4" high by 22" deep. 25 pounds nominal.

MODULATOR

Output Connector	BNC, 75 ohms.
Output Level	Standard: Adj −15 to −5dBm. 1:1 Switch: Adj −15 to −5dBm. 1:8 Switch: Adj −29 to −19dBm/CXR.
Frequency Range	52 to 88 MHz.
Carrier Stability	1×10^{-5}, or ±700 Hz maximum offset.
Output Spectrum	The modulated spectral density is −25dBc maximum at f_o ±[.75 (Symbol Rate)] Hz and −30dBc at f_o ±[1.0 (Symbol Rate)] Hz, where f_o is the carrier frequency.
Spurious Outputs	
In Band	−50dBc, 52 to 88 MHz.
Out of Band	−60dBc, 1 to 500 MHz excluding 52 to 88 MHz.
Harmonics	−60dBc, 1 to 500 MHz excluding 52 to 88 MHz.
Return Loss	20dB minimum.
Scrambling	V.35 compatible, switch enabled or disabled.
Ext LO Input	98 to 134 MHz, +7 to +11dBm, 50 ohms, BNC.

SYNTHESIZER

Output Connector	BNC, 50 ohms.
Output Level	+7 to +11dBm.
Frequency Range	98 to 134 MHz, tuneable in 25 KHz steps ±12 Hz using front mounted minature BCD rotary switches.
Stability	1×10^{-6}.
Spurious Levels	−55dBc both in and out-of-band.

FAULT SUMMARY

Output	Form C relay contact closure plus indicator.
Faults Monitored	CODER Module, MODULATOR Module, DEMODULATOR Module, DECODER Module, SYNTHESIZER Module(s), POWER SUPPLY Module(s).

SWITCHING PERFORMANCE

Data Contact Resist.	50 milliohms maximum.
IF Insertion Loss	.25dB maximum.
Switchover Time	
1:1 Switch	Modulator - 2 sec. maximum. Demodulator - 2 sec. maximum.
1:8 Switch	Modulator - 100 millisec. maximum. Demodulator - .5 to 32 sec., selectable.

DEMODULATOR

Input Connector	BNC, 75 ohms.
Input Level	Standard: −55 to −35dBm. 1:1 Switch: −52 to −32dBm. 1:8 Switch: −42 to −22dBm/CXR.
Frequency Range	52 to 88 MHz.
Return Loss	20dB minimum.
Acquisition Range	±25 KHz.
L.O. Input	98 to 134 MHz, +7 to +11dBm, 50 ohms, BNC.
Descrambling	V.35 compatible, switch enabled or disabled.
Bit Error Rate	Typical E_b/N_o requirements for a BER of 10^{-7} using sequential soft decision error correction:

Code Rate	E_b/N_o 1.544 Mbps	E_b/N_o 56 Kbps
1/2	6.9 dB	6.0dB
3/4	7.5dB	6.9dB
7/8	8.2dB	8.2dB

The above performance shall be provided in the presence of two adjacent like-modulated carriers at a spacing equal to .7 times the data rate using QPSK or 1.4 times the data rate using BPSK. The levels may be 14dB higher in level.

POWER REQUIREMENTS

Input Voltage	103 to 130VDC, 47 to 450 Hz. 206 to 260 VDC, 47 to 450 Hz. −48 VCD, −24 VCD.
Power Consumption	100 Watts nominal.

ENVIRONMENTAL

Temperature	+10° to +40°C operating, −25° to +85°C storage.
Humidity	5 to 95% noncondensing.
Altitude	Up to 10,000 feet operating, up to 50,000 shipping.

APPENDIX B

ORGANIZATIONS CONTACTED DURING TECHNOLOGY SURVEY

The table in this appendix lists the organizations and people contacted during our technology survey activity. We thank them all for their willing assistance. Without their help we could not have been successful in our MITS II analysis effort.

TABLE B-1 ORGANIZATIONS CONTACTED IN TECHNOLOGY SURVEY

ORGANIZATION	TECHNOLOGY INTEREST	CONTACTS	PHONE NUMBERS
Access Corporation Government Systems 700 North Fairfax St. Alexandria, VA 22314	Microfiche Stack Loader	Joseph Connelly	(703) 683-4000
Access Corporation 4815 Para Dr. Cincinnati, OH 45237	Microfiche Scanner	Newton D. Baker	
Analogic Audubon Road Wakefield, MA 01880	Array Processors for Image Enhancement	Frank Csencsits	(617) 246-0300
Bell & Howell, COM Division 16691 Hale Avenue Irvine, CA 92714	Com Recorder	Robert Ricketts	
Coherent, Inc. 3750 Monroe Ave. Pittsford, NY 14534	Laser Subsystem for the Fiche Recorder	Peter Emmel	(716) 248-8480
Collimated Holes, Inc. 460 Division Street Campbell, CA 95008	Fiber Optic Components in the Microfiche Scanner	Daniel J. Dickerson	(408) 374-5080
Compression Labs, Inc. 2305 Bering Drive San Jose, CA 95131	Scanner's Image Enhancement Electronics Image Data Compressor/ Expander Combination	Peter Lowten	
Data General 9620 Chesapeake Drive, Ste. 102 San Diego, CA 92123	Microcomputers & Minicomputers	Rich Gruenhagen Steve Hetrick	(619) 571-7050
Datagraphix, Inc. P.O. Box 82449 San Diego, CA 92138	Microfiche Recorder & Total System	Fred Hill, Marketing OPS	(619) 291-9960
Digital Equipment Corporation P.O. Box 85033 San Diego, CA 92138	Minicomputers and Microcomputers	Michael Orenich Larry Antinone	(714) 292-1818
Digital Equipment Corporation Personnel Computers 200 Baker Avenue Concord, MA 01742	Microcomputer Subsystems		
E-Systems, Incorporated P.O. Box 226031 Dallas, TX 75266	Microfiche Stack Loader	John Latta Wm. E. Waldrup	(817) 461-3511

TABLE B-1 (cont)

ORGANIZATION	TECHNOLOGY INTEREST	CONTACTS	PHONE NUMBERS
Eastman Kodak 343 State Street Rochester, NY 14650	Total System	David Nadeau, BSMD-BIS	(716) 724-4558
Electro Optic Marketing TI P.O. Box 225012 Dallas, TX 75265	Electro Optical Components	Paul Davis	(214) 995-3821
Fairchild CCD Imaging Systems 3440 Hillview Avenue Palo Alto, CA 94304	Electro Optical Components	Marketing Manager	(415) 493-8001
Floating Point Systems P.O. Box 23489 Portland, OR 97223	Array Processors for Data Compression/ Expansion		(503) 641-3151
GEC Ltd. Hirst Research Center Wembley, Middlesex, England	Electro Optical Components	David J. Burt	
General Scanning, Inc. 500 Arsenal Street Watertown, MA 02172	Optical Scanning Subsystem	Kurt Pelsue	(617) 924-1010
Gould, Inc. DeAnza Imaging & Graphics Div. 870 Lundy Ave. San Jose, CA 95131	Image Array Process System	Jose-Luis Arvizu	(619) 236-0636
Grinnel Systems 6410 Via Del Oro Drive San Jose, CA 95119	Image Processing Electronics	Harley Hallet	(408) 629-9191
Harris Corporation Government Information Systems P.O. Box 37 Melbourne, FL 32901	Microfiche Scanner	Gerry Dugan	(305) 727-4000
Hewlett-Packard 9606 Aero Drive San Diego, CA 92123	Minicomputers and Microcomputers	Jack Gartlan George Weir	(619) 279-3200
Hughes Aircraft Company Image Memory Products 6155 El Camino Real Carlsbad, CA 92008	Image Processing Electronics	G.H. Hershman	(619) 438-9191

TABLE B-1 (cont)

ORGANIZATION	TECHNOLOGY INTEREST	CONTACTS	PHONE NUMBERS
IBM Personal Computers P.O. Box 2910 Del Rey Beach, FL 33444	Microcomputer Subsystems		
ITEK CCD Marketing Lexington, MA 02173	Electro Optical Components		(617) 276-2000
Infodatics 1341 S Claudina Street Anaheim, CA 92805	Microfiche Stack Loader	Don Baker	(714) 635-9500
Image Techniques, Inc. 440 Southlake Blvd. Richmond, VA 23236	Microfiche Recorder	Dean Johnston	(804) 794-6243
Integrated Automation, Inc. 2121 Allston Way Berkeley, CA 94704	Total System Scanners and Scanning	Mike Ott Dave Bereznai David Fain C.V. Ravi	(415) 843-8227
International Imaging Systems 1500 Buckeye Drive Milpitas, CA 95035	Image Enhancement Processors	Don Prather	(408) 262-4444
3M Company 601 Park Blvd., Suite 103 Santa Ana, CA 92705	Total System	Wayne Garrett Robert F. Ricketts	(714) 641-1050
Marinco, Inc. 11760 Sorrento Valley Road San Diego, CA 92121	Array Processors for Image Enhancement		(619) 453-5203
Mekel Engineering, Inc. 777 Penarth Avenue Walnut, CA 91789	Stack Loader and Fiche Transport Mechanism	Maurice Amesbury Jack Van	(714) 594-5158
Microtex Digital Imaging 80 Trowbridge Street Cambridge, MA 02138	Image Processing Electronics		(617) 491-2874
Milron Technology 2805 E Columbia Road Boise, ID 83706	Electro Optical Components		
Numerix Corporation 320 Needham Street Newton, MA 02161	Array Processors for Image Enhancement	Peter Alexander	(617) 964-2500

TABLE B-1 (cont)

ORGANIZATION	TECHNOLOGY INTEREST	CONTACTS	PHONE NUMBERS
OMEX Federal Systems 1730 N. Lynn St. Rosslyn, VA 22209	Total System	Eugene Matullo	(703) 524-3900
Omex 2323 Owen Street Santa Clara, CA 95051	Total System		(408) 727-5801
PRC Government Information Systems 1500 Planning Research Drive McLean, VA 22102	Total System	Jerry Skelton Walt Smith	(703) 556-1359 (703) 556-1423
Photomatrix Corporation 2225 Colorado Avenue Santa Monica, CA 90404	Microfiche Scanner	Mike Schuster Guy Hearon	(213) 828-9585
Photometrics Ltd. 1735 E. Fort Lowell Rd., Ste #3 Tucson, AZ 85719	Image Processing Electronics	Richard Aikens	(602) 323-6080
Quantex Corporation 252 North Wolfe Road Sunnyvale, CA 94086	Image Enhancement Processors		(408) 733-6730
RCA Electro Optics & Devices Solid State Division Lancaster, PA 17604	Electro Optical Components	Charles Newcomber	
Recognition Concepts, Inc. 924 Incline Way Incline Village, NV 89450	Image Enhancement		
Reticon EG & G 345 Potrero Avenue Sunnyvale, CA 94086	Electro Optical Components	Greg Herbson	(408) 738-4266
Saguaro Systems P.O. Box 738 Gilbert, AZ 85234	Consulting Services	Bill Sheppard	(602) 892-2299
Sylvania Systems Group Communications Systems Div. 77 A Street Needham Heights, MA 02194	Satellite Link Interface	Ken Tong	(617) 449-2000

TABLE B-1 (cont)

ORGANIZATION	TECHNOLOGY INTEREST	CONTACTS	PHONE
TI Data Systems Group CA Dept. 063 BC P.O. Box 402430 Dallas, TX 75240	Microcomputer		
Talon Technology Corporation 1819 Firman Drive, Ste. 137 Richardson, TX 75081	Satellite COMM Interface	Lynn Heitman	(214)
Tera Corporation 7101 Wisconsin Ave., N.W. Bethesda, MD 20814	Total System	Jeff Arnold	(301)
Terminal Data Corporation 21221 Oxnard Street Woodland Hills, Ca 91367	Scanners and Scanning	Sam Green A-W Jagau	(213)
Thomson-CSF Components Corp. Electron Tube Division 301 Route 17 N Rutherford, NJ 07070	Charge Coupled Image Sensors	Stephan Barthelmes John Mulroe	(201)
Universal Data Systems 5000 Bradford Drive Huntsville, AL 35805	1200 Baud Modems	George Grumbles, V.P. Marketing	
Versatec 8388 Vickers St., Ste. 104 San Diego, CA 92111	Microfiche Scanner	Ralph Johnson	(619)

END

FILMED

DTIC